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# THE FEBRUARY SCIENTIFIC MONTHLY

Edited by

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THE SCIENTIFIC MONTHLY

FEBRUARY, 1939

# RELIGION IN SCIENCE

By Sir RICHARD GREGORY

EDITOR OF NATURE, 1919–1938

LONDON, ENGLAND

WHATEVER differences of opinion may exist as to the respective fields of religion and science, they meet on common ground in the pursuit of truth and its influence upon human life and conduct. Social ethics are as essential a part of all religious systems as are doctrine and ritual, and their character is determined by both faith and reason. Thus the "Concise Oxford Dictionary" defines religion as "human recognition of superhuman controlling power and especially of a personal God entitled to obedience and the effect of such recognition on conduct and mental attitude"; and the Encyclopaedia Britannica says, "We may define the religious object as sacred, and the corresponding religious attitude as consisting of such manifestation of feeling, thought and action in regard to the sacred as is held to conduce to the welfare of the community or to that of individuals considered as members of the community."

Fifty years ago, the literal interpretation of the Scriptures in the light of modern scientific discovery was the subject of much contentious discussion. Fuller knowledge has shown that the issues then raised were chiefly due to misunderstandings of the meanings of both religion and science. In the sacred writings of the early Hebrews, there are few allusions to what may be termed the rational understanding of the universe or of precise observations such as have been preserved in the records of other ancient peoples. All things were interpreted as testimonies to the wisdom and power of the Almighty and His goodness to man—as subjects of wonder and spiritual exaltation rather than as matters of intellectual inquiry. What is called science or natural philosophy was thus separated from worship of divine attributes. Early Greek philosophers made a similar distinction when they conceived nature as a subject of study apart from religious faith and as a means of discovering natural laws by a methodical application of the human intellect. They were the first to use the word nature to signify this type of objective study.

Christianity is one form of expression of a religious impulse which is universal in human emotional life—primitive or advanced. In common with all religions, its form involves three elements—tradition, ritual and a code of ethics. Tradition teaches the nature of the deity or deities, and conceptions of the earth and man as centers of the universe and life. Ritual prescribes the mode of approach to the deity in a form of worship; and, like the code of ethics, is derived from, and dependent for its character upon, tradition.

With increase of knowledge, modifications of these elements of worship become essential if religious belief is to be a part of progressive human thought

and activities. That such evolution of ideas has occurred is a fact of history, and it may be regarded as the application of discovery, or, from another point of view, as revelation. Only by recognition of this principle can religious forces exert their fullest influence upon intellectual and social activities.

In all primitive religions the earth is regarded as the center of the universe, and the deities as regulating all natural forces, the actions of which might be modified by suitable offerings or sacrifices to the powers controlling them. When Copernicus and Galileo had shown that the earth was only a minor member of a family of planets revolving around the sun, the foundations of all religious beliefs which made it the hub of the visible universe were destroyed, and an entirely new theological structure had to be raised. Newton showed later that the movements of planets and other celestial bodies obeyed a natural law or order, so that it was no longer reasonable to look to them for signs or warnings to the human race. This substitution of permanent natural law for the conception of a world in which all events were believed to be reflections of the moods of benign or angry deities involved a revolution of thought which even now is disturbing to religious beliefs based upon the doctrine of daily supernatural intervention.

### Man and Faith

Just as Copernicus deposed the earth from the position it was supposed to occupy in the universe, so Darwin placed man in a new relationship to the rest of living creatures. It is often supposed that Darwinism leaves ethical and moral ideas out of consideration and stands only for the doctrine of "Nature, red in tooth and claw"; but this is due to lack of understanding of the principle. Evolution embodies the idea of social ethics and makes the welfare of the community the essential purpose of the life of the creature. The view that Darwinism signifies nothing more than striving after personal or national mastery at all costs is a crude misconception of this great principle, and was repudiated alike by its founder and by Huxley, its most powerful exponent, as contrary to the best ends of civilization.

Science is concerned with the progress of knowledge and the evolution of man not only in the past but also in the present and future. The idea that such development is possible is relatively modern. The chief philosophers of ancient Greece held that the Golden Age was in the past and that mankind was receding from it; and the same view of human decadence is given Biblical authority in Genesis. It is quite possible that some savages have fallen from a higher to a lower level of savagery, but this is an unusual course to follow. We need not believe that man has degenerated from a state of perfect knowledge to that of being "born in sin and shapen in iniquity," or that the recovery of his lost position must be looked for not in this world but in the next. The adoption of the degradation doctrine is apposed to evolution as a whole and subservient to all progress.

Whether we look to perfection as having been passed long ago or regard it as the promise of the future, the fact that the spirit of man is ever striving to attain it is of particular significance. There is reason for hope when Divine discontent with life as it is urges men to work for higher things. No progress is possible without aspiration, and self-satisfaction therefore signifies stagnation.

Unlike the beasts of the field, man can make his own environment and so promote the development of any type he desires to survive—poet, philosopher, profiteer or pugilist. This is true of man as "nature's insurgent son," con-

tinually fighting against forces of evil which would destroy him, yet able to survive by the use of his intelligence. He may not know the reason for his existence, but he does know that there is law and order in the natural world on which he lives and that if he breaks them the penalty is inevitable. Whether he believes that this world and the whole universe were brought into being by a Supreme Power or not, he has to obey the laws of nature in order to survive. Belief in such a spiritual force may urge him to high endeavor, but upon him is the responsibility of working out his own salvation.

When Napoleon asked Laplace whether he evoked divine intervention in arriving at his theory of the origin of the solar system, the great astronomer and mathematician is said to have answered: "Sire, I have not found this hypothesis necessary." The reply was, however, not made in any spirit of irreverence, for Laplace was a profoundly religious man, as well as an accomplished courtier, and such an answer would have been regarded as offensive by Napoleon who was, at the time, the restorer of French Catholicism. M. Faye, in his book "L'Origine du Monde," says that in previous theories of the system of the universe the calculations had not been pushed far enough, as by them the universe would eventually become disordered. It was, therefore, assumed that, after long periods, there was divine intervention to restore order; and Laplace believed that his theory made such intervention unnecessary. The fact that the theory is not now held to be satisfactory does not mean, however, that a supernatural factor has to be introduced into the calculations in order to complete them.

Belief in the existence of such an omniscient and omnipotent Power behind the Universe is universal. If religion be understood in the broadest sense as the belief in spiritual being, it may be said that prolonged inquiry has failed to show any authenticated instance of a people, however backward, who do not hold to some form of belief, which, though vague and rudimentary, can be deemed religious. It is difficult to draw a hard-and-fast line between magic and religion; and indeed it is a question whether such a differentiation is essential from the point of view of the inquirer who is attempting to trace the development of the religious idea. For even "magic" implies some form of spiritual influence humanly directed. Belief in the efficacy of magic is as much an act of faith in some form of spiritual action as Christian belief in divine intervention in human affairs; and the essence of a religious belief is that it is an act of faith.

Faith may be defined as a belief which is not dependent upon material evidence or logical demonstration from premises ultimately based upon sensory phenomena (although such phenomena may be invoked to support faith as "proof"); but it acquires its validity from some general scheme or theory of the nature and purpose of "being," "life" the universe, or as the philosopher would say, of "the Absolute" or to use a popular phrase, "the scheme of things." In essence it is emotional: not rational. In its contact with "facts" faith interprets them not by observation and experiment, that is, by the approach of reason and science, which demand proof in the strict logical sense, by reference to phenomena, but it evaluates them by the test of coherence with its theory of life and the universe. Such a scheme need not necessarily be consciously formulated or even realized as a whole. Probably, in the early phases of development, such realization rarely, if ever, takes place, as the minds of backward peoples work concretely and are averse from abstraction.

Whatever may be thought of evolutionary faith, evidence from comparative study shows that there is in the mentality of man a generalized urge towards a belief in spiritual values underlying the material appearances of the universe. This urge is fundamental. Various influences such as the influence of geographical and cultural environment, and possibly mental differences of racial strains, if there are such, have combined to produce the different types of belief and the religious systems which have been followed, or are now followed, by mankind. It is at least significant that in the so-called primitive religions of the less advanced cultures there should be such strikingly close similarities in ritual and belief as have been recorded by the anthropologist. Further, when we try to attain an objective view of the more advanced religions, it is no less striking that they fall into a more or less uniform pattern in regard to the relation of the three elements—tradition, ritual and ethics; in other words, in the relation of belief to worship and the conduct of life. Dissension arises not so much out of the nature of tradition as when interpretation is added to it and made a test of orthodoxy. When there is a difference in the central objects of the various cults, opportunities for dissension are multiplied and reconciliation might seem well-nigh impossible. If, however, the spirit of religion is the manifestation of a fundamental urge, recognition of this fundamental unity in man's emotional and spiritual nature should make possible a certain measure of cooperation on a common basis when the aim is the common good of mankind as a whole.

### Religion and Life

Many reasons have been put forward to account for the origin of religion, but it can not be said that any of them have solved the problem. Ancestor-worship, ghost-propitiation, worship of the soul, belief in spiritual beings, reverence for tribal leaders, and other causes, have all been suggested as originating causes of religious sentiment. Primitive man had no religion except such as was embodied in a system of social virtues. Men possessing these virtues to a high degree, and using them to make the tribe powerful or conditions of life more pleasant, would be esteemed as benefactors or heroes not only during life but after death, and this veneration would develop into ancestor worship and later into soul worship.

If it is assumed that the divine purpose of the existence and evolution of life upon the earth is that man should work out his own salvation, it is difficult to understand what the ultimate gain will be when the earth will no longer be in a condition to maintain life as we conceive of it. All that science can say as to the future of the earth or any other planet or system in the astronomical universe, is expressed in the words of the hymn, "Our little systems have their day: they have their day and cease to be." We may contemplate the progressive development of man and society to whatever stage which satisfies our ideals, but, so far as we now know, the whole phantasmagoria will eventually be dissolved, and the death of mankind will be the final penalty for achieving the highest type conceived by the human mind. This thought should not, however, be subversive of effort and aspiration on the part of humanity as a whole, any more than the individual should neglect noble motive and conduct because he himself has to pass away whether his influence has been for good or evil. Though science is unable to provide any positive evidence for survival of personality after death, it must acknowledge that belief in such survival is a powerful ethical factor in human development. It is just as permissible, therefore, to assume that

another world awaits habitation of an exalted type of humanity after this earth has come to an end, as it is to believe in the eternal existence of individuality.

Whatever convictions may be held as to the future of man or humanity, the standard of goodness is decided by the community. The man who lives a moral life merely because he wishes to save his own soul is little better than an expectant Hedonist; for his motive is personal profit. He may be saved from punishment hereafter by being negatively evil, but his life will be of no benefit to the human race unless he is positively good. What existence awaits us when we are called away we can not say, but we find stimulus and high endeavor in the hope that each thread of life is intended to contribute to the web designed by its Creator. Though science may not be able to contribute much to the ultimate problems of spiritual beliefs, it does teach that every action carries with it a consequence—not in another world but this—to be felt either by ourselves or others in our own time or the generations to come.

Evidence of the progressive development of forms of life in the past and of changes still going on is so convincing that it may almost be regarded as a law of Nature. In so far, therefore, as evolution signifies an orderly succession of organic growth, few would venture to deny the fact; but how and why such changes are brought about has not yet been established beyond discussion. Whether organic evolution has proceeded by gradual development of small variations of structure and habits or by the sudden appearance of new forms is a question for naturalists to decide among themselves in their search for natural causes. The court of observational science is concerned only with evidence which throws light upon such causes and efforts without assuming the existence of supernatural design or intervention. Whether behind the natural causes producing evolution there is a transcendental principle or architect is not the concern of naturalists but of other philosophers. Their position is that even if the facts of organic evolution can not be explained by existing knowledge, they will be explicable when more is known about natural causes and consequences, without introducing a *deus ex machina* to conceal our ignorance and suppress the pursuit of objective evidence.

We have passed the stage when, in order to afford support for Christian belief in general, and the Mosaic an account of creation in particular, it was only necessary to find naturalistic or rationalistic explanations of miraculous and other elements in Biblical records. Such attempts to fit all new knowledge into a system of thought having no claims to scientific accuracy or intention served no useful purpose to the Bible or to science and to-day would satisfy neither historical students nor naturalists. A much sounder basis can be found by applying evolutionary principles to religious thought and by studying sacred books as steps in the story of man's progressive discovery in theology. It is only by disregarding history that the idea of a fixed and final theology becomes possible. In science, there are no final interpretations or unchangeable hypotheses; and if the same principle were recognized in theology, religion would share some of the vitality of the natural sciences. Evolution can be regarded by the theologian as merely the means of creation; and the conception of gradual development is not incompatible with Christian theology. It is through the acceptance of the idea of evolution in the spirit as well as in the body of man that the partition which formerly separated religion and science is being dissolved.

All religions—primitive and advanced—include ethical ideas relating to the

human conduct and its supreme end. The highest form of religious ethic is that in which the aim of conduct is complete and implicit obedience to a code which is conceived as the will of God. In the less generous manifestations, this obedience may be rendered against natural inclination as an outcome of fear; for "Fear of the Lord is the beginning of wisdom." It may then degenerate into a formalism as lifeless, and even more harsh, than that of those systems which stress ceremonial purity. On the other hand, it may become a joyous and spontaneous acceptance of a mode of life, such as it is conceived would be consonant with the nature of God, subject to such limitations of the flesh as are ineradicable—the idea of saintliness. Hence arises the desire for uprightness as an end in itself, either with a view to reward, if not in this world, in another; or pursued selflessly for its own sake. This concept of religious ethic, which rests ultimately on personal and intimate relationship between the individual soul and its God, has led to the highest idealism in human conduct; but it has also degenerated into many unpleasant forms of exaggerated and distorted continence and self-torture in the monastic, ascetic and mystic conceptions of the holy life.

The aberrations of religious systems of ethics, or rather of their more fanatical followers and exponents, have been pursued in face of the exemplars they had before them, in some instances at least, in the lives and teaching of their founders, such, for example, as Christ, Gautama Buddha and Confucius. These exemplified a practical morality which, had it been adopted by those who came after them, might have served the needs of a united mankind—united, that is, in all that is essential in making for good living and well-being. Such ideal systems, however, it is said, were not adaptable to the conditions of a work-a-day world. But this is true of every measure of reform, and constitutes the justification of its claim to the title of "reform"; while its success lies in the fact that it has forced every-day conditions to comply with its demands, and not that it has adapted itself to them. It has still to be proved by trial that of the ethical systems, which have emerged in the great movements for religious regeneration and revival in the history of the world, no one in its respective field and in some of its more fundamental principles has yet delved sufficiently deep into the elemental constituents of man's nature to attain a rule of conduct, which even such a purist in ethics as Kant might have accepted as law universal.

Since the beginning of the great scientific movement of the nineteenth century, many attempts have been made to comprehend science and religion in one philosophic system. The problem may be approached from two points of view —one of which is based upon naturalistic reasoning and the other upon what may be termed inner reason or faith. Professor Emile Boutroux discussed these different aspects in a valuable volume published thirty years ago.[2] Whatever the relation between religious belief and religious practice, the essential principle in religion is faith in the existence of spiritual powers or action which transcend natural laws and life. To many people, universal belief in such supreme powers is sufficient proof of their reality. There is, of course, a difference between arbitrary belief founded upon spiritual conviction and conclusions derived from verified and verifiable scientific observations and hypotheses; and it is difficult to find a common standard for the two outlooks. Professor Boutroux suggested that they can be reconciled in the ideal of duty or service which summons us beyond the specifically human to a noble struggle and a

[2] "Science and Religion in Contemporary Philosophy." 1909.

great hope, an ideal which implies faith and love, and demands a Supreme Being with whom mankind can be in communion. His suggestion may not satisfy the rigorously logical minds of scientific philosophers or theologians; nevertheless, it is in the light of service to high ideals that science, without which we can not live, and religion, without which most people would see no meaning in life, can find a common field for their activities.

### Science and Social Ethics

In recent years, there has been much discussion of the ethical or social consequences of the application of mechanical and other scientific discoveries to industry. In the early days of the industrial revolution in England, there was little of the scientific spirit in industry. The discoveries of science were used with as much indifference to science as to humanity. The inventions of the eighteenth and early nineteenth centuries came from the workshop rather than from the scientific laboratory. Machines were devised and operations developed largely by trial-and-error methods, and academic research had few points of contact with industrial practice. The characteristic of the present age is the utilization in industry of principles, properties and products revealed by scientific research whether carried on solely in the pursuit of knowledge or with a practical purpose in mind.

It is sometimes suggested that progressive science and invention are responsible for the troubled condition of the world at the present time, owing largely to overproduction. It would be just as reasonable to blame the Almighty for good harvests or for providing in some parts of the world all the means of existence for primitive man without the need for labor. The fault is not with those who create gifts for men's comfort and enjoyment but with the social system which prevents their easy distribution and use.

National progress must be more striking, more potent to observation than observation in man's ethical and social development; and it is also no more than to be expected that there should be a lag in the latter. It was more than a generation after the initial movement of the industrial revolution in Britain that progress in other directions began to affect the population of the country at large. To any one who takes long views and compares conditions of to-day with those of a hundred to a hundred and fifty years ago it must appear a rash statement which characterizes man's progress in that period as one of command over the material resources of the world only. This is to deny certain patent facts. For example, in every department of human life—at any rate, in Great Britain—there has been in that period a stupendous awakening to a sense of social responsibility—a very real development in man's mentality and the growth of society. In effect it now demands that the latest results of all branches of scientific research, but more especially of those affecting hygiene, both physical and mental, should be applied to the conditions of life of the population as a whole. This is not philanthropy or religion as such in the narrow sense, but arises from a broadening in the conception of the relations and obligations of man to man.

When this movement towards social betterment began more than a hundred years ago, the study of economic and social problems was not envisaged as a matter of scientific research, but in so far as it stood apart from philanthropy, as a question of philosophic principle, as in the doctrines of the Philosophic Radicals, Romilly, Bentham and the Mills, father and son. Some or most of these men were regarded as virtually atheists, but on these questions they were allied

with Quakers and other philanthropic and religious reformers. Bentham's formulation of the ethical basis of conduct and the "end" or purpose of the state as "the greatest good of the greatest number," if a philosophic dogma, at any rate comes as near to being a normative principle in applied social science as was possible in his day.

In alliance with other influences at work in the community at that time, it fostered the sense of responsibility which demanded a more equitable distribution of the wealth derived from the industrial revolution and the introduction of machinery. It is the main theme of the social history of Britain in the nineteenth century—a history covering the crusade against child labor, which was sapping the vitality of the nation, set up by Lord Ashley (Shaftesbury) exactly a hundred years ago, factory legislation, the extension of the franchise, the education acts, the growth of trade unions, the amelioration of conditions affecting wages, hours and surroundings of labor; the after-care of labor in old age pensions and compensation for accident, the medical inspection and feeding of school children—these measures forced on the education authorities by men of science—improvement in school buildings and in housing, prison reform and reform of penal law, in short, a thousand and one social reforms, many of which have been enacted as a direct outcome of the results of scientific research on the conditions inimical or conducive to well-being in human life in the environment of modern civilization. Out of the philosophic and philanthropic ideals of the early nineteenth century there has grown up a vast and practical social science which gathers up and applies the latest results of scientific research in all branches of the circumstances and conditions of life which affect the mind and body of man as an individual and as a member of the state.

Apart, however, from the mental and moral effect, difficult to gauge, of improved conditions of life the increased application of the results of scientific research to those conditions has been accompanied by a parallel growth in the sense of responsibility in the community towards every member of that community—the concept that of the wealth of the community a toll must be taken to ensure that from the cradle to the grave each individual member shall be ensured a certain measure of healthy nourishment, opportunity for growth in body and adequate instruction in mind by education to become a useful member of the community, with assurance of medical attention in employment, a measure of sustenance to the unemployed and of provision for old age.

This is not communism, unless it be communism to admit that I am my brother's keeper; but it is precisely towards this admission that practical application of the modern science of man is directing mankind, both as an inference from the study of societies of the past and the humbler societies of to-day among primitive peoples, as well as from a diagnosis of the elements which appear to make for progress in modern civilization. It is true that a modern society with a sense of responsibility, but which, it must be admitted, we have not yet fully attained, is only now approaching the position of the primitive group in its sense of responsibility to its members. That is perfectly true, but the advance, the spiritual progression, lies in the range of that sense of responsibility. Whereas in the primitive form it embraces the members of the blood kin only, or those of the local group within which the members are more or less intimately acquainted, within a modern society it may reach out to embrace all members of a great nation, and possibly when warring creeds agree to sink their differences, it may extend to all men of

good-will to whom the dignity of man as an individual entity transcends racial and political boundaries. When, if ever, that comes to pass, it will be possible to gauge how far man has advanced along the road of spiritual as well as material progress. To many, the way seems long to go. The urge of nationalism and its ideals has diverted the thoughts of peoples—both fascist and communist—away from the main stream of human progress into narrower channels in which rocks and rapids threaten at every turn to shipwreck all that is best in civilization.

If science has a spiritual message, its function would now seem to be to take a leading part in the process of producing a civilization which will be based upon its service. In the history of early civilizations, a condition of stagnation and of internal dissension has usually preceded their decline and extinction. The end has come through conquest by military forces of a superior type or by the invasion of hordes of barbarians whose only motive was plunder. It used to be suggested that modern civilization would be saved from this fate by the powers with which science has provided civilized peoples to protect themselves against overwhelming numbers having only primitive weapons. The perils which threaten modern civilization are not, however, so much from the greater numbers of peoples who may eventually possess powerful appliances of war as from the very peoples who have themselves perfected such weapons. Efficient barbarity made no distinction in the great war between the destruction of masterpieces of architecture and ammunition dumps; and, since then, aerial bombing of any center of life or of beauty seems to be accepted as a means of offensive action by nations which claim to be civilized. Instead of science having to save modern civilization from being overwhelmed by barbarous hordes, it seems to have provided the means of self-destruction. Man has advanced so little in spiritual evolution that he is just as much a barbarian in his use of aerial bombs and poison gas as he was when his weapons were only clubs and arrows.

Such prostitution of the rich gifts with which modern science has endowed the human race must be condemned by all who see, in the general feelings of civilized people to-day, incipient stages in the development of characteristics which distinguish man from other living creatures. The law of the jungle is that of the battle to the strong, and the race to the swift. It recognizes no right to live except by might; destroys the weak: has no sympathy with suffering: and no sense of the highest human values. In the struggle for existence, man has survived because his physical structure and intelligence have enabled him, individually and in communities, to master the things which would destroy him. His social instincts have at the same time been extended from the family to the tribe, the nation and the empire, and will reach their highest and best when they embrace the world.

The virtues which should be prized most to-day, if civilization is to mean the evolution of social ethics to a noble plane, is regard for spiritual values, love of truth and beauty, righteousness, care for the suffering, sympathy with the oppressed and belief in the brotherhood of man. Any nation or people which separates itself from the rest of the world in the name of race or religion, and cultivates ideals of conquest by force in order to assert its claims, is not assisting human evolution but retarding it. Science has made the world one through the facilities of communications and transport now available; and it recognizes no political or racial boundaries in its fields of knowledge. Among modern social and intellectual forces, science alone speaks in a tongue which meets with uni-

versal understanding. The conception of science as a social factor intimately linked up with human history and human destiny gives a new meaning not only to scientific research but also the position of citizens who are engaged in it. Both rightly and wrongly, science has been blamed for much of the wastage of life which has been brought about by the rapid applications of scientific knowledge to purposes of peace and of war. Men of science are, however, citizens as well as scientific workers; and they are beginning to realize their special responsibilities for securing that the fruits of scientific knowledge are used for human welfare. They can no longer remain indifferent to the social consequences of discovery and invention, or be silent while they are blamed for increasing powers of production of food supplies, providing means of superseding manual labor by machines and discovering substance which can be used for destructive purposes. It would be a betrayal of the scientific movement if scientific workers failed to play an active part in solving the social problems which their contributions to natural knowledge have created.

The view that the sole function of science is the discovery and study of natural facts and principles without regard to the social implications of the knowledge gained can no longer be maintained. It is being widely realized that science can not be divorced from ethics or rightly absolve itself from the human responsibilities in the application of its discoveries to destructive purposes in war or economic disturbances in times of peace. Men of science can no longer stand aside from the social and political questions involved in the structure which has been built up from the materials provided by them and which their discoveries may be used to destroy. It is their duty to assist in the establishment of a rational and harmonious social order out of the welter of human conflict into which the world has been thrown through the release of uncontrolled sources of industrial production and of lethal weapons. By combining exalted spiritual ideals with results of research in the fields of natural knowledge, it is possible now to hope and to expect scientific guidance not only towards individual fitness but also towards a higher human perfection and a condition of social life which will make the world truly a celestial dwelling-place.

NOTE: Sir Richard Gregory delivered lectures upon the subject of this article before the Carnegie Institution of Washington on December 8 and before the American Association for the Advancement of Science on December 29. Sir Richard and Lady Gregory sailed for their home in England on January 5.

# MATHEMATICS, THE SCAFFOLDING OF SCIENCE

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I SUPPOSE most experimental physicists approach their subject in an attitude which visions nature as governed by certain fixed laws which are unique and fundamental in expression and which are, in fact, independent of our way of thinking about the phenomena. They are then apt to regard mathematics as a means to facilitate the consequences of the manipulations of these laws. It is true that mathematics serves the end in question when that service is demanded of it; but I think we are coming, consciously or unconsciously, more and more to a realization of a more dignified rôle for mathematics. In this rôle, through the richness and complexity of its possibilities of formal relationships, it is able to find in its own structure elements which can be associated with the elements of our intuitive observations in the sense of a one-to-one correspondence, and can build between those elements, often in many ways, a scaffolding of relationship which the physicist ultimately moulds into his mind structure to the end of realizing what he calls an understanding of the phenomena.

Once the laws of a group of phenomena have become moulded into mathematical form in this manner, the physicist proceeds to endow the elements of the mathematical scaffolding with the maximum amount of some vague extraneous attributes which he thinks of as substance and reality. Then, if, as a result of new developments and of advances in our knowledge, it becomes necessary to enrich the mathematical scaffolding, or even to alter it, many feel intuitive difficulty in that they have already placed the seal of their approval upon the old form, have incorporated all their intellectual devotion in it and have dressed it in clothes of reality and substance, which clothes have now become so conspicuous as to seem to be elements essential to the operations of the structure. The mathematical structure itself was a pliable thing, lacking desire to protest against development in its form. While the structure was unclad, none were worried when in the processes of integration of some equation some mathematician said: "Let us change the variable from $x$ to $y$, where $y = \pi x^{\frac{1}{2}}$". Once the elements of the mathematical structure have been clad in the raiment of substance and reality, however, such changes are apt to disconcert the mind of the experimental physicist, for the clothes he has prepared for the structure which his brain has incorporated will fit no other structure.

Thus, to take a very simple and historical case, the whole essence of what is called the mathematical theory of gravitation is to the effect that a planet moves at each instant in such a manner that its acceleration towards the sun is inversely proportional to the square of its distance therefrom. Immediately this fact is stated, however, the laboratory mind seeks for underlying reasons in which, following analogy with other experiences, it introduces the concept of force emanating from the sun, which force is responsible for the acceleration concerned. The preparation of the mathematical apparatus for the calculation of this force in special cases leads to the concept of a quantity V, the potential, having a value not only at the place where the moving thing is, but everywhere else in space, even though there be nothing there, a

value governed by the well-known equation

$$\nabla^2 V = -4\pi\rho$$

Not liking to leave a dignified quantity like $V$ supported by all the mathematical mechanism of potential theory suspended in the cold of space, without anything to live in, the physicist proceeds to envision some kind of a medium in which $V$ may, as it were, be dissolved with the promise to precipitate itself in the form of its derivatives at any point where substance appears to be acted upon. $V$ is like a spider hiding in its web to do something to every fly which, in the shape of unsuspecting matter, makes its appearance. Directly the medium has been established all sorts of questions are invited, such as those pertaining to what it is made of, what is meant by its existence, and whether it has the same kind of properties as those possessed by other things which have been called media, even though those properties may have nothing whatever to do with the functions of the medium in its purely mathematical sense.

Some of these elements are well exhibited by a contemplation of the classical electromagnetic theory, which visions a number of particles, let us say electrons and certain other things called electric and magnetic fields, all governed by the system of equations

$$\frac{1}{c}\left(\rho u + \frac{\partial E}{\partial t}\right) = \text{curl } H \qquad (1)$$

$$\rho = \text{div } E \qquad (2)$$

$$-\frac{1}{c}\frac{\partial H}{\partial t} = \text{curl } E \qquad (3)$$

$$0 = \text{div } H \qquad (4)$$

$$\left(E_i + \frac{[w_i H]}{c}\right) e = \frac{d}{dt}(m w_i) \qquad (5)$$

It is not necessary for me to define everything in these equations. It will suffice to say that they concern themselves with the motions of a group of electrons under their mutual influences. In the customary method of expression of the subject, equations (1) to (4) enable one to calculate certain quantities called electric and magnetic fields $E$ and $H$ in terms of the positions and motions of all the electrons. The process of calculating the motion of any one electron is to calculate at it the electric and magnetic fields in terms of the motions of all the other electrons and then to substitute in equation (5) to obtain the motion of that electron itself, which electron I have called the $i^{th}$ electron. It will readily be seen that there are as many groups of three equations (the three corresponding to the three dimensions in space) as there are particles.

Now, it is perfectly possible to reformulate the content of these equations, so that the final expression of affairs involves nothing about $E$ and $H$ at all; and the solutions of the equations represented by this final state of affairs represent all that anybody ever believed himself concerned with in the classical theory of electrodynamics. What then is the real purpose of the introduction of $E$ and $H$? I think the answer is to be found in the following: If we wrote down all the differential equations obtained after the elimination of $E$ and $H$, their forms would have a complexity of structure such as would render it impractical for the mind to coordinate them or, and this is the important point, to see readily and in manipulative form the mathematical properties contained within them. By the introduction of the quantities $E$ and $H$, we have an intermediary scaffolding. It is true that that scaffolding arose through the medium of intuitive thoughts about electric and magnetic fields which grew up gradually from the birth of the subject; but it could have arisen as the result of a pure mathematical device designed to express the relationships between the motions of the electrons through an intermediary scaffolding which had the power to exhibit in forcible form the characteristic properties of those motions. It is inter-

esting to inquire in what way the intermediary scaffolding performs its functions.

It is well known that solutions of equations (1) to (4) for a charge free region can exist in the form of what we call plane waves; and, for such solutions, the vectors $E$ and $H$ lie of necessity in the planes of the waves and are perpendicular to each other. Although the plane waves exist only in free space, it is easy to see that they can originate through the equations from electronic motions which are possible. It is also easily seen that these plane wave fields, when acting upon other electrons which they encounter, in their passage through space, will, through equation (5), cause them to move also in the plane of the waves, at any rate approximately. In so far as in the old classical theory the phenomenon of the reception of light was supposed to come about by the ultimate motion of some electron in the receiving apparatus, which electron was controlled by the light, we see that the waves of $E$ and $H$ in question have just the mathematical properties to give rise in this electromagnetic picture to a correspondence with what in classical optics was said to be the fact that light vibrations take place in the plane of the wave front, a conclusion demanded by the phenomenon of polarization.

Thus, while in electromagnetic theory —classical theory, that is—it is the motions of the electrons in the source which are responsible for the light, and the motions of the electrons in the receiver which are responsible for the detection of the light, the relationship between these motions which is characteristic of polarization does not make its appearance in a simple form *directly;* but it is very emphatically brought forth by the structure of the intermediary scaffolding involving $E$ and $H$. The scaffolding is, of course, of our own creation.

I like, in fact, to regard equations (1) to (4) as providing definitions of $E$ and $H$, which defined quantities are then for use in substitution in (5). One may well protest that he can not discover laws of nature by definition. That is true, but even as a carpenter fashions his own tools to a form suitable to the work he wishes to do, so the mathematician can, through definition, endow the quantities of his structures with properties which anticipate the service which they will be called upon to perform. Herein, I think, lies the reason why, in spite of the complete evaporation in modern quantum theory of that fifth equation concerned with the motion of an electron in a field, equations (1) to (4), which really form, as I have said, the definitions of the vectors $E$ and $H$, continue to survive. They survive because, being definitions, they can never be discarded on the basis of being wrong. They can only be discarded if the quantities defined are found to have no use.

One may question why I have been so concerned in emphasizing the definitional nature of $E$ and $H$ and have appeared to begrudge them all elements of what the laboratory physicist would like to call their "reality." The reason is that it is those clothes of reality which tend to encumber them with so much which can discredit them. The practical physicist, who "likes to know what he is talking about," will seek a definition in terms of which he can measure $H$. Somebody tells him that $H$ is to be measured by the force on the unit pole. Of course, a unit pole doesn't exist; but that does not trouble the practical man. He thinks of a long bar of iron which he tells us behaves as though there were magnetic field-producing substances called positive and negative magnetism concentrated at the two ends. He will admit that even in terms of his own concepts as to the logic of things, the points in which the magnetism is concentrated have no meaning except in the light of small volumes which, however, are so large that they contain a very large number of molecules, each of which is itself a little magnet.

This does not worry the laboratory man very much because he says his apparatus is very big compared with molecules, anyhow. That is all very well, however, until in some of the important ramifications of electrodynamics he finds it necessary to talk about the variation of the magnetic field throughout a region which is not only smaller than the region containing his large number of molecules, but is smaller than a single molecule, is smaller than an atom, and is, in fact, an electron itself. Then, of course, I encounter difficulties in some of the fine-grained applications in knowing what is meant by the *force* upon a unit pole. If a physicist tells me that it is the mass times the acceleration, I am worried about the question of what that person means by the mass of an entity which in terms of his own philosophy does not exist; and, I am still more disturbed on seeing a relativist round the corner who, I know, will demand that the mass of the thing which does not exist shall vary with its velocity.

Now, usually the physicist doesn't worry about these matters. He goes ahead with his magnetic and electric fields and makes correctly the calculations of the final quantities which are of concern in his measurements. What kindly guardian angel looks after his mental operations and steers him clear of the troubles I have envisioned? The guardian angel is really a kind of anesthetist who anesthetizes part of his brain to hide from him what he is really doing. He thinks he is using $E$ and $H$ in terms of the definitions provided by his unit poles and the like; but in actuality he is using the kind of $E$ and $H$ that I have envisioned.

There is another aspect of the function performed by such quantities as $E$ and $H$, and that is the aspect of enrichment of the relationships involved. Before the days of electromagnetic theory we had only electrostatics in electricity; and, if in those days we had spoken of electrons, the theory of their motions would have been of simpler form, and would not, in fact, have conformed to the phenomena of optics at all. There could have been meaning to motions of charges under the mutual influence of electrostatical forces.[1] However, the enrichment of the possibilities of relationships between the motions of the charges secured by the incorporation of the vector $H$ permitted a wider range of possibilities in the relationships in question, a range wide enough to include the phenomena of optics in their story. The electrostatic case still has meaning as a special case of the more general formulation.

We may enrich still further the possibility of relationships between the motions of the charges by incorporation of additional elements in the scaffolding. Thus, it is possible to have relations in which $E$ is replaced by another vector $D$ in equations (1) and (2) but not in equations (3) and (5), while $H$ is replaced by $B$ in equations (3) and (4) and also in (5) but not in equation (1). Such equations are usually referred to as the equations for a material medium because a kind of averaging process of the equations for free space leads to equations of the form in question. However, the point which I wish to emphasize at this stage is that the equations involving these four vectors $E$, $H$, $B$ and $D$, would have meaning as applied to charges in free space; and, would, in fact, constitute, as I have said, an enrichment of the possibilities of these equations.[2] As

[1] I, of course, use the word electrostatics as implying a calculation of the fields of the charges from the same laws as those for charges at rest, even though the charges themselves be moving. I do not wish here to imply by the term electrostatics an absence of motion of the charges.

[2] I must remark that the incorporation of the extra vectors $D$ and $B$ calls for the incorporation of two additional vectorial relations in order to give enough equations to determine the vectors in terms of their charges and of their motions. The elementary form of these relations usually adopted is $B = \mu H$, and $D = kE$. However, the additional relations appropriate to all the considerations involved are more elaborate than this.

a matter of fact, I think it is possible to regard certain comparatively recent generalizations of the older electrodynamics as nothing more than an enrichment of relationships provided by the incorporation of additional vectors in the scaffolding.[3]

Physicists have for the last two or three hundred years sought to explain the actions of those parts of the universe which are not directly observable to their senses through the means of mechanical models. From a mathematical standpoint this amounts to trying to picture the sub-grained universe as governed by the same kind of mathematical laws as the laws which have been found serviceable in the coarse-grained universe perceptible to our senses. In the coarse-grained universe there are things with which mathematics concerns itself, there are springs and weights, there are planets and suns. These things have many attributes other than those which figure in the mathematical relationships concerned with the coarse-grained story of their mutual influences. These things are really irrelevant to that story, but they are often so conspicuous as to leave the unsophisticated with the feeling that the bodies concerned would be meaningless without these attributes.

In the sub-grained universe typified by the universe of the atom, the model analogy leads us again to think of things, electrons, neutrons, and the like. We are willing to forego for these things some of the irrelevant characteristics of the coarse-grained problems of which we seek to make the atom the analogy. Because the earth in going round the sun exhibits, as a result of its motion and the direction of its axis of rotation, the phenomena of seasons with the growth of green fields and flowers at one time of the year and their disappearance at other times of the year, we do not demand that an electron revolving round the nucleus of an atom shall also have green fields and the like upon it. However, the line of demarcation between what we do demand and what we do not demand is not always very clearly marked; and some of the irrelevant elements which are content to stand aside and make no complaint about the lack of call for their services are apt to arise in protest in the naive mind if some condition should arise out of the mathematical reasoning which would seem very disagreeable to these irrelevant properties, in the sense that they could not stand for it in the large-scale things of life. Thus, if in the sub-grained mechanism of some atomic phenomenon it were necessary to imagine one particle to pass right through another, leaving it quite intact, there would probably be protests in the minds of many, concerned with the dictum that two things can not occupy the same place at the same time; and this would be so, even though the laws of the subject which were relevant had no protest to make against this passage of one particle through another.

And so, as I have said, a theory of the atom sought form in a picture in which there were things which moved in accordance with sets of laws something like those of astronomy, and it was hoped that these motions could be regarded as taking place in some all-pervading medium. Physicists are frequently concerned with questions about the reality of things; and, if the kind of model of the atom of which I have spoken had been successful, there would have been the same sort of reason for saying that the particles in it were real as there would for saying that Neptune was real at the time when it had been discovered as being the influence necessary to perturb the planetary motions to their observed forms, but had not been seen. The particles in the atom in these preliminary attempts did have the attributes of large-scale things in the laws which governed their motions. As re-

[3] I refer to Max Born's theory of electrodynamics.

gards the medium to which they supposedly transmitted their story, however, there was even less of intuitive reality. We had become sufficiently sophisticated to avoid requiring of this medium that it should have the characteristics of known media which were irrelevant to its functions. We did not worry ourselves as to whether this medium, this aether, should freeze in the cold of interstellar space and whether, therefore, there should be icebergs of aether floating about. What made the aether seem so very unreal, however, in regard to what were the rather vague conventions as to the standards of reality of the day was the fact that in the things actually relevant to its functions it acted according to laws different from that of any medium with which we were acquainted.

Even with the foregoing concessions in respect of freeing the necessary elements of the atomic world from too many of the embarrassing characteristics which we had been accustomed to associate with reality, it still refused to work properly. The motions of the parts of the atoms didn't do the right things and the aether didn't transmit the story in the right way.

When it appeared that the types of mechanism to which I have referred could not be strained in any reasonable way to tell the story desired, a change in the mode of thinking became inevitable. However, drastic as that change appeared at the time, it was a timid change as we see things to-day. The electrons and so forth in the atom were allowed the prestige of continuing to occupy it and of conforming to some of their rituals of the past, as exemplified by their obedience to the old laws of motion. However, when it became necessary for them to do anything which really mattered, it also became necessary for them to do that thing in a manner governed by no scheme of forces with actions anything like those of our previous pictures. The atom was supposed capable of existing in a number of different states, in each of which it carried out the ritual of the older laws, but did not do anything of importance. It was supposed, however, that a kind of revolution could occur at any time which would convey the atom from one state to another. The story of the revolution itself was not contained in the atom's ritual.

And so, as the development of thought progressed in these directions, models of the atom and the like lost more and more of that naive substantiality which characterized the models of the past. The laws of physics assumed a more and more abstract form. The laboratory physicist became more and more unhappy, and the theoretical man, glorying in an ever-increasing realm of sophistication, talked a language which only he could understand. There was a sort of reversal of simplicity and complexity. The things which were simple in this new era of thought were the abstract laws which controlled atomic processes, and the things which were complicated were the laws of matter in bulk.

In spite of all that may be said, however, for the discarding of models and for the purity of abstract processes, one has to realize that the mind itself is an essential partner in that greater scheme of things which, through the aid of abstract theory, seeks to coordinate, and in this sense understand, the phenomena of nature. In the last analysis, all theories must be moulded to a form in which the brain can respond to them. To attempt anything else is like asking a violin to resonate to electromagnetic waves. Indeed, it is very difficult for the human mind to think at all unless it has something to think about; and he who has discarded models with contempt will probably find, if he is honest with himself, that in his thinking he has replaced these models by other intuitive guides which stimulate his mind to action and which, if absent in one who

listens to him, will leave that one unable to deny, but without conviction, until he has succeeded in growing his own intuitive thought structure in terms of which his brain may function. An intuitive mechanism in the mind functions probably more strongly if one becomes conscious of what it is and what its limitations are; and so it is pertinent to ask what is to replace the intuitive concepts of models in an age which has discarded those models.

Any mathematical physicist who surveys the development of his subject over the past two centuries can not help but be impressed by the survival of the standard mathematical processes of physics through many revolutions in the philosophy in connection with which they are used. Fourier series and their like appear again and again. Those old warriors, the mathematical theorems which express the decisive characteristics of analytic functions, stand immorally ready to serve the needs of any master who is willing to invoke their service. They are like the hired soldiers of days gone by, and even of to-day, willing to fight and sell their own particular form of skill in any cause. The processes of expansion in Fourier series and the like are to be found through many generations of mathematical physics. The fact that the integral of $\sin mx \sin nx$ is equal to zero when taken over a suitably chosen interval when $m$ is not equal to $n$, and is finite when $m$ equals $n$, can be regarded as the basis of resonance in the classical dynamics of an undamped vibrating system. A similar kind of property is used again and again. It is this property which, in the guise of resonance, provides for such primitive account of the photoelectric effect as is given by classical theory, and which provides the classical theory of optical dispersion and the like. It is again this property in another form which is the thing which really does the trick in the quantum mechanical theory of the photoelectric effect, and of optical dispersion and the like. It is a similar property of normal functions which becomes the mathematical representative of Bohr's selection principle. The same old mathematical warrior, serving a different master, it is true, and clad in different armor so that he is hardly recognizable in his new rôle, shows his same old metal when he draws the sword for action; for that sword strikes very much in the same way in the old theories as in the new.

It is the existence of product terms involving products of the velocities of two coordinates in the expression for the kinetic energy which, in classical dynamics, provides by the usual mathematical processes for such phenomena as are exemplified in the gyroscope where the velocities associated with one coordinate control the forces which come into action in altering the magnitude of another. It is this fact, the mechanism of whose existence is so pictorially evident to us in the gyroscope which, in equally conclusive mathematical form but with less intuitive appeal, is the origin of the mutual induction of currents in electrodynamics and of the forces between current-carrying circuits. It is this fact which again and again in the modern theories of atomic structure brings about the influence of one coordinate upon another and so reflects the existence of some physical fact.

I have sometimes said that a large part of mathematical physics is concerned with talking about functions in regions where they are analytic in terms of the distances of the point concerned from regions where they are not analytic and in terms of the nature of the abnormality of the function in that region. Thus, we talked about the magnitude of the potential as a function of its distance from a point charge. Mathematically, a point charge is the region where the function ceases to be analytic. This

sort of statement exhibited in the various forms of Green's theorem represents properties of abstract entities, which properties stand ready to be correlated with observable properties in electrodynamics, in hydrodynamics, and so forth. All they need is christening; and once christened they are adopted into the family and made to do their same old work in very much the same kind of way as that in which they have done it before. About all that happens in the transfer of these theorems from one master to another is a change in the form of the heraldic uniform. These uniforms are as a rule unnecessary and are even oftimes an encumbrance to the duties of the mathematical warrior.

If I were to extrapolate the idea perhaps a little further than I should, I might say that the mathematical physicist, consciously or unconsciously, is like a plumber with various tools shaped to various purposes and well tried for the doing of certain things, because he made them or gradually developed them for such types of jobs. When he comes to some new branch of physics where his services are needed, he pulls out his old tools and tries to find whether the job can be done with them when used perhaps in different ways and in different orders, but always in such a manner that when the story is really told it is a thing which is really characteristic of some particular tool which causes that tool to serve its purpose in the job. If, therefore, we seek aids to intuition after discarding models, I suggest that we seek them in the properties of these tools. For my own part, I have frequently found it of use to transfer my thoughts from a battle between forces and motions in dynamical systems to a battle between mathematical terms and operations, and even to personify these terms and operations. I see a third differential coefficient in the time as something which makes more use of a high-frequency vibration than does a first differential coefficient.

When I look at the familiar old differential equation

$$a_0 x + a_2 \ddot{x} = 0$$

I recognize that it is because its two terms differ by an even number of differentiations that I get a conservation of something in the form

$$\frac{d}{dt}\left[\frac{1}{2} a_0 \dot{x}^2 + \frac{1}{2} a_2 x^2\right] = 0.$$

I realize that when the original equation is generalized to the form

$$a_0 x + a_1 \dot{x} + a_2 \ddot{x} = 0,$$

it gives lack of conservation in showing that

$$\frac{d}{dt}\left[\frac{1}{2} a_0 x^2 + \frac{1}{2} a_2 \dot{x}^2\right] = -a_1 \dot{x}^2,$$

where the lack of conservation is symbolized by a right-hand side being always of one sign.

I observe that if I write down the still more general equation,

$$a_0 x + a_1 \dot{x} + a_2 \ddot{x} + a_3 \dddot{x} + a_4 \ddddot{x} + \cdots = 0,$$

and multiply all the way through by $\dot{x}$, I can integrate all the terms involving even orders in the differential coefficients so as to represent them in the form of $d/dt$ of something; and this is because at each operation one of the members of the product of two derivatives increases in order by one, while its companion decreases in order by one, so that the two approach each other in order by two and eventually integrate out. On the other hand, the terms involving originally only odd orders must of necessity grind down on integration by parts to something which is the integral of a square and so they lead to lack of conservation. And so, I regard my odd power terms as dissipators, and keep them carefully in mind as such in introducing them as soldiers in the fray.

And so I would agree with the lamentations of him who, in the discard of mechanical models, finds it difficult to pin upon something to think about, and would suggest that in his mind he re-

places the battles between forces, inertia, and the like, with battles between mathematical terms, functions and derivatives, endowing some of these conceptions with sorts of personalities, and choosing as the basis of their incorporation in theories the purposes immediately to be served.

It is by no means visionary to hope that one may adjust his intuitions so as to work with realms of concepts other than those with which our immediate predecessors have worked. A mechanical explanation of things in the ordinary sense of the word was by no means an intuitively satisfying explanation before the time of Galileo. However, those of us who were born in the late Victorian era were bred on the old mechanics, and the custom was to try to see all new phenomena in the light of a mechanical picture. Thus, when in my youth anybody wished to try and make me understand how it came about that an electrical circuit composed of a condensor, an inductance and a resistance, in series could oscillate, he would call attention to a weight vibrating in oil, at the end of a spring and would say: "This thing $L$, a self-inductance, in the electrical problem is like the mass $m$, of the weight. The resistance $R$, to the flow of the electric current, is like the resistance $r$, offered by the oil. The condensor in the electrical problem performs the function of the spring in the mechanical one. By thinking of the weight, spring and oil, I hope you will understand why the electrical circuit oscillates." Now, to show that the mechanical concepts have no *a priori* right to intuitive fundamentality, I may remark that to-day the youngsters start to play with radios before they go to college, so that they meet electrical circuits before they meet springs and weights in their mechanics classes. Perhaps the situation with you is like what, from a well-known professor of electrical engineering, I have learned it to be with some of his students in these days. Perhaps you understand electricity better than you understand dynamics. Perhaps I should have started with electricity and now say to you: "From your knowledge of electricity I will proceed to explain why it is that a weight tied to one end of a spring and hung in oil bobs up and down in the way it does. Now, you all know that if you have in a radio circuit composed of a self-inductance $L$, a resistance $R$ and a condensor $C$, it will, under suitable conditions, oscillate. If stimulated by an external radio wave, it will build up an oscillatory current which is greater the greater the degree of tuning, etc., etc. Now, I want you to think of this weight as something like the self-inductance, this oil as something like the source of electrical resistance in the wire, and so forth. I hope that by drawing upon your knowledge of how an electrical circuit oscillates, you will be able to appreciate why and how a weight bobs up and down on the end of a spring."

I think that the physicist would gain by incorporating to a greater extent than he does the mathematical mechanisms, as I may call them, into his intuitions, by endowing the mathematical processes with the same degree of intuitive satisfaction as that formerly accorded to his models and with a more clear recognition of the correspondence between the mathematical operations and the physical facts.

I may illustrate my meaning by referring to a statement customarily used in connection with the restricted theory of relativity to the effect that similar experiments performed upon systems moving with relative constant velocity give identical results. To me the doing of similar experiments has absolutely no meaning without further clarification. Thus, if I simply take the words at their face value, I might say that I was doing similar experiments upon the two systems if, standing on each of them successively, I measured the wave-length of the sodium D line emitted by some star. In this case, however, as every one knows, I should obtain different re-

sults, the difference being, for the most part, an exemplification of the well-known Doppler effect. Of course, the relativist would tell me that I had not done the same experiment, and if I asked why, he would tell me that in each system I ought to have my own star to move along with me; but I am left a little dissatisfied until I inquire further into the matter and, that in this matter I am not the only fool in the universe, there is the evidence that again and again this Doppler effect is cited by those who do not quite understand the theory of relativity as an objection to it. What then is the solution of the matter?

When the mathematician considers a set of differential equations he is apt to speak of the conditions which must be specified in order that the set shall have a unique solution. He refers to the fact that it is necessary to assign a certain number of quantities in addition to the differential equation in order that the complete story shall be told. Thus, in classical astronomy, the orbits of the planets are uniquely defined, as are the motions in those orbits, by the assignment of the positions and momenta at some instant. I like to regard the doing of an experiment as the fixing of those quantities which it is necessary to fix in order that the differential equations of the subject shall have a unique solution. The meaning, then, of doing the same experiment in two different systems is the assignment of equal numerical values to the corresponding quantities which determine the solution. The doing of two similar experiments would be meaningless were the equations for the two systems of different order, for example.

I have said that in classical astronomy the planetary motions are determined by the assignment of the positions and momenta at some time. This is because the equations are of the second order. Had they been of the third order, the assignment of mere positions and momenta would have left an ambiguity in the solution; and, had there been a physicist who thought the equations were of the second order when they were really of the third, he would have come to the conclusion that doing what he called the same experiment twice over would in general give different results. He might even formulate a principle of indetermination as a result. Indeed, this matter has a bearing upon the so-called principle of indetermination in atomic structure; but of that I will not speak now.

The higher the order of the differential equations and the greater their number, the less they say, and the more is left to be said by the supplementary initial or boundary conditions. The beginner in relativity theory, having encountered much difficulty in building up equations which are invariant in the restricted theory, is astounded when he hears the general theory talking of relations which are invariant under *all* transformations of coordinates. The equations of the general theory acquire this apparently remarkable property by the characteristic of saying less than those of the restricted theory, leaving more of the story to be told in the boundary conditions. By saying sufficiently little it is possible to increase the generality of truth of that which is said. Indeed, it is obvious, for example, that if a differential equation should be of infinite order, it would say nothing, which is a sufficiently non-compromising statement to be invariant under all transformations of coordinates.

The general theory of relativity provides a good illustration of how the facts of nature may be connected in all sorts of different ways, each of which is capable of giving rise to a different set of intuitive concepts. The nature of the intuitive concepts is, in fact, determined largely by the types of coordinates chosen. Thus, for example, if I represent the story of planetary motion in terms of a suitable system of coordinates, the restrictions upon the problem engendered by that choice throw the laws

into a form in which the story is told in terms of equations in which there are, for the most part, accelerations on the left-hand side and functions of the position on the right, so that out of this picture can be grown the old intuitive concept of forces and the like. If I choose other sets of coordinates the story must be told in another way as regards any intuitive concepts with which one may accompany it.

If I were asked to express in very brief popular form the essential thing which is accomplished in the general theory of relativity, I do not think I should talk much of curved spaces, and the like, but should give the following analogy:

Suppose an investigator should be sent into a country to investigate the laws of the country. Let us suppose that he was a rabid non-smoker, an absolute teetotaler and endowed with the plague of rheumatism. He brings back his report to me. He gives me a very concise and beautiful statement of the parliamentary procedure, except that in it I find woven into the description long discourses upon the unhealthiness of the atmosphere and the impossibility of correct judgment being formed in it which I ultimately conclude arose from his having observed somebody smoking during the deliberations. A similar situation may exist with regard to matters pertaining to strong drink, and he may imply that the variations of humidity of the conference rooms are totally abnormal in relation to what it seems they should be from other matter in his report.

When I read this report, I shall come to the conclusion that it consists of two parts woven together, something depending upon what was really happening in the country, and something depending upon the idiosyncrasies of my investigator. Of course, if I knew those idiosyncrasies I might make due allowance for them, but I should always be a little uncertain because, after all, they really might have a very vile brand of cigar in that country. The best thing I could really do would be to send into the country a whole army of investigators with all sorts of idiosyncrasies and accept only that which they all agreed upon.

Now, when we formulate the laws of nature, many interesting things present themselves. In the old days we thought that they were all fundamentally characteristic of nature, but the ultimate philosophy which we have been driven to by the theory of relativity leads us to the belief that some of these interesting things are really inherent in nature herself, and some of them are a consequence of the way in which we have made our measurements. These latter things may be also very interesting to us, as interesting as was the effect of the change of climate on the rheumatism of the investigator cited above. However, it is important to be able to separate the consequences of our two observations into these two categories—those which are fundamental and those which are inherent in our measurements. You may say, why separate them? Perhaps the answer is, that any extension of knowledge results from meditation upon the implications of the laws of nature as we see them, and it is only worth while to meditate upon the parts which are significant. It may be of great value to meditate upon the governmental structure of that country to which I referred as regards its potentiality for war and the like; but it will be of little international value to meditate upon my own rheumatism, however important that may be to me.

To come now a little nearer to the actual procedures involved, I may say that all our information about nature is obtained from our measurements. We may fix the collision of a comet and a planet by measuring the distances $X$, $Y$, $Z$, north, west and up of, let us say, Washington, and the time $T$ at which the collision occurs. We may fix the

event in another manner. We may measure certain angles with telescopes. I must not pursue this too far into its detailed ramifications. Let it suffice to say that it is as a result of such measurements, and in terms of them, that we express the laws we find. Now the relativist sets out to find how much of what he expresses in this way is independent of the particular ways in which he makes the measurements. That part is inherent in nature. The great elements of skill involved in his mathematical procedures are involved in his finding out how to say—in mathematical equations—these absolute facts about nature in such a way that, if he should tell the story in terms of other types of measurement, the ultimate story would be the same.

In spite of all the discredit that modern science has thrown upon the intuitive concept of reality, you may maintain that you can not escape the very emphatic consciousness of the substance of things. You will tell me that when you bang your head against a wall, it seems most emphatically evident that there is reality in the wall and that the wall is there. You will protest that all things are not shadows. You will tell me that you can touch things, you can feel things, and that deep down in your very bones you believe that they are there. I sympathize with your feelings, but I must warn you that all you have as your criterion for the existence of whatever it may be that you are thinking about, all you have for your criterion for the existence of the reality of this "substance," is the set of impressions you get from your senses; and the abstract principles of science will, if they have been properly chosen, reincarnate in the approximate and crude form of your senses that concept of reality with which you started, and which seemed so very substantial and meaningful to you. They will construct this reality, not with simplicity, but with the appropriate complexity which should adorn it. I fear there will be many things about it of which you will feel rather ashamed; but humbled in its reincarnation, it will nevertheless be sure of the ground left to it.

And so we begin to see that, in line with the spirit of this philosophy, there is an artificiality in the old reality, and a true reality in the new artificiality. The new reality is not a development of an enhancement of the principles of the old; but the old is rather a rickety, somewhat illogical, vague and incomplete structure which comes nearest to respectable form when reincarnated out of the principles of the new.

If, in spite of all I have said, you still seek to prune your own concepts into something which, over the whole realm of nature, has those elements of reality desired by your primitive senses, then I fear you are doomed to disappointment. At best, you are doomed to the life of one who seeks an ideal which becomes more and more remote as he continues to pursue it. Like the moon, the ideal will always seem to lie behind the mountain ahead; or like the rainbow which seems to descend to the earth at some definite spot, it will move away from you as you approach the spot where it seemed to be. It is said that God fashioned man in His own image; but it is very evident that it is man who has fashioned God in his image. If, in your search for that which the imp in your soul has told you is final and which is reality, you should beguile some sorcerer to bring your ideal to you for a moment for your inspection, you will see but the image of your own face in the picture. You will see the mechanism of that thing which was the old reality fighting like an octopus to find holds for its tentacles upon the true realities of nature; and as you examine more closely the form and actions of that octopus you will find that it is none other than your own brain.

# SOME PHILOSOPHICAL REFLECTIONS OF A BIOLOGIST. II*

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## A Biological Principle of Uncertainty

There is another phase of the problem which merits consideration. It is a well-known fact that protoplasm has never been completely analyzed chemically. We start in the laboratory with dead protoplasm, of course, but inasmuch as there is no loss in weight in passing from the living to the dead state, it is to be assumed that every chemical component of the living is present in the dead protoplasm. As every one knows, however, it is not the number of chemicals or their weights which gives character to protoplasm; it is the *organization* of the substance that is the essence of life, chemically or biologically speaking. Now to what extent is it practically or theoretically possible to ascertain the precise nature of that organization? It is, of course, a fundamental character of living protoplasm that it is a dynamic system, that it is not characteristically at rest, but is always in process of change. This fact alone complicates the problem of a satisfactory chemical analysis; but let us look a little further. If "life is response," if protoplasmic activity is interaction between protoplasm and environment, or rather between protoplasm and *change in the environment* (stimulus), what is the logical conclusion as to the possibility of reducing biological activity to a chemical formula with proper mathematical dressing? There seems to be no possibility of beginning to attack the living organization of the molecule of protoplasm, without bringing about responsive change in the protoplasm.

"... we must remember," says Niels Bohr ("Atomic Theory and the Description of Nature," 1934), "that the investigation of the phenomena of life not only leads us, as emphasized in the article, into that domain of atomic theory where the usual idealization of a sharp distinction between phenomena and their observation breaks down, but that, in addition, there is set a fundamental limit to the analysis of the phenomena of life in terms of physical concepts, since the interference necessitated by an observation which would be as complete as possible from the point of view of the atomic theory would cause the death of the organism. In other words: *the strict application of those concepts which are adapted to our description of inanimate nature might stand in a relationship of exclusion to the consideration of the laws of the phenomena of life*" (pp. 22–23).[3]

Physicists tell us that it is impossible to determine with complete accuracy both the location and the velocity of movement of a particle at the same time, because any effort at measurement will inevitably involve either a change in the velocity or in the location. The same paradox seems to confront us with reference to protoplasmic behavior. There seems to be no conceivable possibility of ascertaining the nature of protoplasm at any given moment, in view of the fact that any attempt at investigation involves a change in the environment which either destroys the organization

* Concluded from the January issue.

[3] I am indebted to Dr. Arthur E. Ruark for reference to Bohr's book, which was read after the preceding and following paragraphs had been written.

or which at best may be responded to by a change of organization. The impossibility arises from different conditions in the two cases—or does it? In the case of the electron, we are debarred from measurement for lack of a measuring rod of sufficient delicacy to avoid disturbance of the object to be measured, or because the instrument itself may be changed in the act of application.

The same statement could be made with reference to protoplasm, but the difficulty is perhaps due not only to the relative coarseness of the implements we must employ, but also to the inherent sensitivity of the object to be measured. Its sensitivity is the condition of its being the object of measurement, that is, of its being living protoplasm. Biology has its own "principle of uncertainty" in that there seems to be no theoretical possibility of determining precisely the nature of organization in a system which of its own inherent nature changes its organization every time we make any attempt to inquire into that organization. I think we might even say that the protoplasmic complex changes its organization *defensively* (and perhaps offensively as well) with every attack upon it. Should any one question the propriety of the term "defensively," let judgment be deferred until we have arrived at a later paragraph. It seems safe to say, at least, that there can be no ultimate solution of the problem of determining the organization of vital substance until we find a means of attack to which the substance is not responsive. At present that seems to spell a logical impossibility.

My vision of the future encompasses no conceivable state of biological and chemical science when all or any biological phenomenon will be reduced to chemical and physical terms. Rather, I envision an eternal game of battledore and shuttlecock between biologists and chemists. Repeatedly, the biologist must say to the chemist or physicist, "I have carried my investigation to the point beyond which I can not go by methods available to me; now you take it as a problem of biochemistry." I contemplate also that after a time the chemist or the physicist will have to say, "I have made my contribution and have arrived at a point beyond which chemical or physical methods will not avail. I pass it back to you for a while." And so it may go. We seem to forecast eternal cooperation in a task without end!

The contemplation of an endless task may offer discouragement to some persons. To such it can only be said: If you are made of the stuff that can find encouragement and hope only in the expectation that the task to which you have set yourself will ultimately be entirely completed, with nothing left to be done by those who come after, it is perhaps better that you should keep out of biological science—or any science; and perhaps I should add also, keep out of philosophy. Look for peace of mind in some more lowly undertaking.

## A Biological Principle of Relativity

The recognition of life as interaction between protoplasm and environment seems to lead us inevitably to what may well be called the Biological Principle of Relativity: we learn absolutely nothing about how an organism or a cell lives except as it behaves in relation to something else. This seems so obvious that I need take little time to discuss it. The relativity of all knowledge is such an old philosophical concept that the novitiate in philosophy would be presumptuous in attempting its exposition. Nevertheless, one may be permitted to try, even at the risk of being somewhat trite, to show how the biologist arrives, and seemingly must arrive, at his own principle of biological relativity.

If the biologist is to deal with life, he must first ask himself how he can distinguish living from non-living things. Without discussing all the tests that may

suggest themselves, we can say that the most generally applicable practical criterion is this: that living substance responds to a stimulus by an adaptive response. It should perhaps be explained here that the biologist uses the expression adaptive in a specialized sense, or perhaps in two senses. Like every one else, he calls it "adaptive" when an organism does the fit and proper thing in the circumstances presented, as when a wren, finding no hollow tree handy, makes its nest in a tomato tin tacked onto a post. Again, on the other hand, the biologist uses the word "adaptive" as almost synonymous with "responsive"—perhaps on the theoretical assumption that the response will be of a nature that will in the majority of cases, but not necessarily in all, be useful or adaptive in the ordinary sense. Jumping from the frying pan into the fire is only one illustration. There is presumably no particular advantage in being broiled rather than fried, or vice versa indeed, but it is a good general rule to go somewhere else when it gets too hot where you are. There are cases too, in which a directly suicidal act is a service, not to the individual but to the species.

After this digression let us return to the consideration of our practical criterion of life: living substance responds to a stimulus by an adaptive response—not just any response, but one that is adaptive, meaning one that has some relation to the welfare of the living substance. Then, if we ask what is a stimulus, we have to say that it is an appropriate change in the environment—not just any change, but one that leads living things to give an adaptive response. To test its viability one puts an egg in an incubator; had it been placed in cool moist soil and failed to develop we should not have regarded it as a bad egg. On the other hand, one puts an acorn in moist soil rather than in a dry incubator. We must find the right stimulus in each case. Obviously, we are getting into another circle. A living thing is something which responds adaptively to the sort of thing that will make the living thing respond adaptively. We had as well say: a living thing is something that acts like a living thing!

It comes back to the significance of "adaptive response." I think that we can properly say that a living thing is something that tends to look after itself or its kind, something that tends to meet the world, not passively, but both defensively and acquisitively. It tends not only to resist the destructive or encroaching pressure of outside objects but also to use such objects to promote itself or its kind. It tends to grow and to multiply, not for itself alone, but for the promotion and increase of its kind, even though for the production of its kind it must sacrifice some part or the whole of itself. Personal sacrifice, by the way, is not an exclusive characteristic of man or of life at any particular level. The worker bees that give up all capacity for self-propagation to spend their entire lives in the protection, feeding and nursing of the larvae and of the queen, the one reproductive member of the colony; the drone bee that sacrifices his life in the mating process; the paramecium that divides into two; the tiger that goes into battle for its young; the plant or animal that gives off ova, pollen or sperm; the seed that sprouts and so hastens the end of its own individual existence; the man that lays down his life for country or principle— these are all obeying the same law of nature. It is not necessary to assume that all such acts are done by intention; it is enough to observe that it is in the very nature of life that these things are done.[4]

[4] The "Bible of Nature" may not be an altogether inappropriate term, since one can find in nature support for all kinds of social theories, by the simple device of picking out particular natural phenomena and disregarding the context. It does seem, however, that the very least

"Self-preservation is the first law of nature." That, indeed, is a very crude and inaccurate statement. "The preservation of the kind is the first law of living nature" would more nearly fit the facts of biology. The ecologist would indeed go farther, conceiving of neither the individual nor the species as the ultimate value. Both paleontology and everyday ecology show that nature sacrifices the species to the good of the community as a whole, with the same equanimity as she displays in sacrificing the individual to the good of the species. That is something to give mankind pause —if anything can. I should say, however, that the first principle of biology is that there is within living substance a condition of internal pressure, tending toward expansion of self or kind; call that pressure by a fancy name if you will. Perhaps the chemist would say that we have in protoplasm a highly complex chemical system that is never in equilibrium, that has always unsatisfied bonds. I do not know just how the chemist is to express the broader manifestations of this instability of equilibrium—this universal tendency to bring about equilibrium, and therefore death, in some units that others may continue in a state of activity.

Assuming that we know anything, it seems to me that one thing we know is that we can not know anything except with reference to something else, that all the knowledge we have is relative. That being the situation, we can not expect to reach an ultimate and complete solution of any question that is presented to us, and it does not seem to require a great deal of scientific or philosophic discussion to establish the fact, if facts have any value to us. What the physicists have done recently is to demonstrate experimentally and theoretically that this is a scientific truth with reference to the movement of electrons. That I should take to be an important contribution to physical science, and a discovery of great interest to philosophy and scientists in other fields.[5] It may perhaps serve to remove the foundations from some of the cruder doctrines of mechanism. It does not, however, undermine mechanism completely, and, as far as I am capable of judging from what little I have heard or read, it does not even establish or weaken the doctrine of free will: regarding these two conflicting ideas, we are left where we always were and where presumably we shall always be, since the answers to these questions seem to lie without the circle in which we have to live and move and have our being.

It does appear that a great deal of useless speculation may be avoided if we could regularly recognize some simple facts about how knowledge is gained. I have heard speculation on the question of whether, if we know everything about free hydrogen and everything about free oxygen, we could necessarily predict that the union of these two elements in proper proportion would give us a substance with the qualities of water. Ap-

evidence is available to support either extreme of individualism—the one that says: "Every man for himself and the devil take the hindmost"; and the other that would make the interest of the least efficient paramount, and—devil take the foremost! Organic nature does not seem to work in either of these ways. After alluding to the oft-emphasized competitive struggle of animals for food, water and safety, Allee remarks: "It is only lately that equally plain evidence has been massed to show that animals cooperate usually as unconsciously as they compete to secure these same necessities." At the risk of incurring criticism for choosing a text from nature and applying it to human affairs, I may give personal endorsement to the familiar view that that portion of mankind will best survive that shows capacity for the most genuine and intelligent cooperative effort.

[5] Since this was written and presented orally, a paper by Dr. Harold Jeffreys, entitled "Science, Logic and Philosophy" has appeared in *Nature* (141: 672–676 and 716–719, 1938). "The Heisenberg uncertainty," he says, "is no new discovery in principle, but an estimate of a lower limit to the old uncertainty which was never neglected except by misplaced optimism."

parently, the conception of "emergent evolution" is based in part, at least, upon the assumption of a negative answer to questions such as the one just stated. It is with no little diffidence or sense of temerity that I frankly express my whole-hearted conviction that there is hardly a better example in our language of the drowning of thought in a sea of words. All that we know about hydrogen is relative to something else; and we can know nothing of oxygen except in its relation to other things. When one reads this statement: "We do not arrive logically at water by studying hydrogen and oxygen," the question may well come to mind: Do we on the other hand arrive logically at hydrogen or oxygen without studying water? After we have absorbed this profound statement and the equally profound responsive query, where have we gotten? Exactly nowhere! Emergent evolution merely brings us back to the principle of relativity in thought just as an earlier discussion seems to lead us to the conclusion that life itself is relative. Wherein is one discovery of fact, or one change of kind, any more "emergent" than any other?

### *Vitalism, Mechanism or Neither*

A little while back it was suggested that some of my remarks might lead me to be branded as a vitalist in the metaphysical sense of Driesch and others. The tag is emphatically disclaimed because I conceive of nothing more futile than an argument over whether the vitalist or the mechanist has a truer idea of the meaning of life. To my mind, and I admit its deficiencies, the vitalist is merely one who closes his mind against all but one side of the picture, and similarly the mechanist is one who refuses to look at the plain facts that loom so large in the mind of the vitalist. It seems to be a very simple task for the vitalist to take the well-known facts of embryology and so to apply them as completely to demolish pure mechanism. Apparently it is just as easy for a mechanist to blast the underpinnings out from beneath the position of the vitalist by showing the vanity of any attack upon biological problems from a purely vitalistic base. Superficially the mechanist seems to be in a little better position, because he can go on being a laboratory biologist, while a vitalist, if "deeply convicted," so to speak, must lose hope of even a fair measure of progress in the pursuit of biological science. It is, I am sure, not just a coincidence that the leading exponent of the alleged principle of vitalism abandoned biology for a seat in the sanctum of a sister discipline—philosophy; nor is it strange that the most outspoken mechanists seem generally to be those who in their work have least to do with living beings as such.

Now I fully realize the position of embarrassment in which one may seem to place oneself if, with two seemingly mutually exclusive hypotheses, one does not choose between them. It might be said that this shows a lack of decision or of courage. But we do not have to choose between supposed alternatives until we know what they are and whether or not they actually are mutually exclusive. The difficulty is in the lack of acceptable definitions. Just what is meant by mechanism? In one sense it seems to relate to machinery, but I know of no machinery which is not conditioned upon some sort of protoplasmic activity. If it means merely that biological phenomena are reducible to chemical and physical terms, the first and perhaps the weakest answer has already been given, namely, that no biological phenomenon has yet been reduced to chemical terms. How could it be, when the protein molecule plays such a part in protoplasmic behavior and not even the structure of one protein is yet known?

The second answer is that I am not

sure that chemical and physical principles have yet reached the stage when we can properly appraise their theoretical applicability to biological phenomena. When the physical scientists, starting out with clearly non-living materials, can give us even the rudiment of a working system that will grow and reproduce, behave and misbehave, like an organism, it will be time enough to take notice of the claim that biological phenomena are special cases of physical chemistry *and nothing more.* Such a statement should not, of course, be taken to mean more than it says. The scientific spirit is not tolerant of assertions that this or that can never be done. One recalls the story of the mathematician who demonstrated conclusively that a baseball could not be thrown to describe a curve. Is it in his honor that the modern spectators rise to their feet in the seventh inning? To say that living phenomena are not explicable in terms of present-day chemistry and physics is to utter a truism. To say that they can never be explained (or that they can be explained) in terms of future chemistry and physics is to make unwarranted assumptions as to what the chemistry and the physics of the future will be.

"Bridging the gap" between living and non-living substance may well command the keenest interest and the most capable effort. Abiogenesis, or "spontaneous generation," as an article of faith and a beam of hope, has arisen more than once in the past—only to fall as often as it has arisen. It may well rise again—it must arise, one might think—and it may fall—who knows? It may be an aid to clarification in thought if one recalls Preyer's three categories: *biosis,* with continuing display of life; *abiosis,* destruction of the organization bringing actual death; and *anabiosis,* referring to suspension of living activity without fatal disorganization, as with the dried tardigrades which "came to life" after years of apparent death. Abiogenesis, actual gap-bridging, seems to involve a start from clearly non-living material rather than from originally known living material which has been so modified as to seem for a period, and until a proper change of conditions, non-living.

On the other hand, before we flee from the mechanistic stronghold into the camp of the vitalist, let it be observed that the vitalist admittedly knows nothing about the so-called vitalistic principle, and even boasts that he can know nothing about it. Obviously then, it is not a biological or scientific principle, but a philosophical one, if it is a principle of any kind.

One speaks only for oneself. Another may find it agreeable and helpful to proclaim himself a pure vitalist or a pure mechanist. In either case, he is performing, as I see it, an overt act of faith; he takes a position which can not be securely grounded in present-day scientific knowledge. He has wandered out into the field of philosophy or of religion, as he has a perfect right to do, and possibly a duty. I merely say that, for my own personal wanderings into such fields, both vitalism and mechanism are superfluous paraphernalia. Apparently the great majority of biologists have not aligned themselves with either party, and this, I take it, is not because they are habitual mugwumps, but rather because neither party has yet given a fully intelligible and acceptable platform. To me it is quite conceivable that this may in time prove to be no issue at all, but it is possible also that it may prove an eternally insoluble one. Meantime, the pure vitalist and pure mechanist undoubtedly serve a useful purpose to the most agnostic of us, in that they each keep the other from deluding us into the belief that he has the whole truth. While it may be fairer to say that some find their own conception of mechanism a helpful pro-

visional hypothesis, and so with vitalism, nevertheless, it does not appear altogether improbable that in the year 5001 there will still be debate on this subject, as well as on that of predestination versus free will.

*Some Further Principles of Biology*

Now I comment briefly on what I conceive to be some fundamental principles of organic life. I think first of the stream of life or the principle of *continuity*. In the line of ancestry of any living organism there seems to be no break, no discoverable beginning. Organic beings and organic substances die and are lost to the stream, but the stream flows on. It is a one-way stream—like the flow of time. There are no reversals or only temporary and insignificant ones compared with the steady forward flow. In the class of reversals we might classify phenomenon of de-differentiation, second childhood, etc., short-lived reversals preceding the end of life, or other short-lived and adaptive de-differentiations which seem comparable to a backing up for a fresh start.

The second principle, which is closely allied to the first, relates to the condition of *incessant internal organic pressure*. If we pour water into the open space of a weathered and creviced rock, the liquid flows out into every nook and cranny under the influence of pressure largely from without—gravitation, including its manifestation as atmospheric pressure. If we could sterilize the entire crust of the earth, leaving only a small seed plot of living organisms, all experience leads us to believe that, given a sufficient amount of time, the organisms would multiply and severally fill every occupiable niche. In this case, the pressure seems to be largely from within. It is this expansive force of life to which we allude when we speak of "internal pressure," the tendency to take in and assimilate everything assimilable—to grow, to multiply, to crowd everything else out.

The exalted Psalmist, considering the relation of man to his environment, and addressing the Almighty, exclaimed, "Thou makest him to have dominion over the works of Thy fingers, Thou hast put all things under his feet"—a sublime conception, but a poetic exaggeration. Not yet has man gotten quite everything under his feet, but if he has not, it is for no lack of mighty and unremitting effort; for, if man does not now have dominion over the tides and the winds, the insects and the pathogenic organisms, it is not because of any want of the spirit of imperialism. So it is with insects and mollusks. A wise old friend of mine once remarked that the great object in life of an oyster was to convert the whole world into oyster; and if one considers the avidity of an oyster for food and its reproductive capacity, the statement seems not wide of the truth. The biotic potential of the oyster is limited more by outside forces than by its own lack of biotic ambition.

Combining the first two principles into one, we might compare the stream of life to a great river that is continually in flood, and constantly losing over its banks enormous quantities of water while the stream always flows on with approximately undiminished volume. An infinitely greater volume of water has been lost than remains within the banks, but that which is within the stream has an unbroken history of water from its remote and undiscovered headwaters to the mouth—if there be a mouth.

Thirdly, since all organisms in nature are exposed to others, each lives under a condition, not only of pressure from within, but of *pressure from without*. The two-fold organismal pressure may well be compared to atmospheric pressure. In the biosphere, just as in the

atmosphere, nature abhors a vacuum, and living beings are crowded into every possible nook and cranny penetrable in any way by protoplasmic substance. The sand along the banks of the lake, the dark, cold depths of the sea with pressure of a thousand atmospheres, the masses of coral rock, the hot springs, the subterranean waters—all, so far as they are endurable by protoplasm, have their populations of living beings. Protoplasm seems to strain itself to the utmost tolerable limit to obtain dominion over the earth; and each kind crowds the others and limits their abundance, although each may in the long run promote the general welfare.

The inevitable state is one of *approximate equilibrium*, a fourth fundamental principle that runs through the whole organic world. Of course, the physiologist knows about this condition of equilibrium within the cell and between the cell and the surrounding body, but the condition does not prevail there only. The individual as a whole must be in equilibrium with its environment, or it fails to be living. Organisms never live independently, but always in communities made up of themselves and of other organisms of the like or different kinds, so that community life is a fundamental principle; but this, after all, is merely another phase of the law of equilibrium between individuals and species. Within the community, every organism, every kind of organism, finds its *niche*, by which we mean that it finds its function in the general cycle of life.

A fifth biological principle is that of *individuality*. There is always the tendency to form larger or smaller aggregations of protoplasm, each of which seems to possess a measure of individuality. It might, of course, be questioned whether bacteria have individuality, but I can scarcely conceive of the evolution of bacteria—that is to say of the beginning of new kinds—unless the new kinds have arisen from individual variations, which seems to imply individuality.

A sixth fundamental principle seems to be that of change in kinds or species, or *evolution*. If we compare communities in different parts of the world where there seem to occur approximately the same conditions of unlimited external pressure and where very similar niches are to be filled, we generally find different species of organisms filling the niches; or if, with the paleontologists, we look into past times, there seem to have prevailed comparable niches with still other species to fill them. Contrast, for example, the great groups of herbivores of North and South America, Africa and Asia, or those of the present with those of Triassic times; contrast also the large and small herbivores of land with the minute, almost microscopic, vegetarians of the seas. It would be superfluous now to go into all the arguments that lead to a belief in evolution, in descent with modification. We may as well, I think, regard evolution as just as fundamental a principle of life as the tendency to grow and multiply. Possibly it is another aspect of the condition of internal pressure, with some significant part played by the conditions of external pressure to which allusion has been made.

Put in other words, evolution is another expression of the adaptive capacity of protoplasm—always the interaction between "living" and "non-living" as well as between one living thing and other living things. The individual adapts itself to a changing environment as long as it can; when it can no longer adapt itself, it succumbs—it dies. The species adapts itself to changing environment so long as it can; when the capacity for adaptation fails, the species succumbs—it becomes extinct. The statements just made carry an air of plausibility, but, even if their truth be granted, they do not tell us what we want to know—and that is how the

changes, adaptive or not,[6] occur. That is the question to which the biological, biochemical and biophysical sciences address themselves. We study the physiology of the organism to learn how it fulfils its responsive functions. We study the origin of species to see how they (or the germ cells) have responded to whatever they have encountered. Do the statements cited, then, have any value? Only if the attitude of mind, the point of view they imply is helpful, which may or may not be the case. *Persistence with modification* of the individual through "ontogenetic time" and *descent with modification* of the species in "phylogenetic time" may be different aspects of the same basic principle. *Growth, multiplication* and *diversification*, if not one and inseparable, seem at best inevitably linked with the phenomena of life. Physiology and evolution would then be different phases of the one primary division of biological science. Anatomy (and the anatomical aspects of embryology) would be subsidiary to physiology (including the physiological aspect of embryology); morphology and taxonomy would be subsidiary to the physiology of species (evolution); genetics and ecology would be subsidiary to both but more particularly to the latter. Evolution might, indeed, be described as the physiology of the germ cells—for even the most enthusiastic Lamarckian must admit that evolution operates only through modification of germ cells.

As we now approach what may seem to be an over-delayed end, let it be remarked that the spirit of man demands a goal. It appears to be in our very nature to have a purpose, to be aligned with some sort of dependable plan carrying the promise of the ultimate attainment of higher values. Although it is quite without my present province to discuss this aspect of the philosophy of life, I must make this parting allusion in order both to show that this phase of life has not escaped our general recognition, and to emphasize the fact that I conceive of no contradiction between what has been said and the validity of scientific objectives or of social ideals.

[6] Reference has already been made to a seeming, if not a real, ambiguity in the use of the term "adaptive." Personally, I am not prepared to assume that all structural and functional qualities of organisms are "adaptive" in the sense of being useful, although excessive maladjustment is self-destructive. On the other hand, I can see no escape from the conclusion that all living phenomena, even the most useless, if there are such, are "adaptive," in that they owe their origin to protoplasmic responses to something. The muscles of my ear may be presumed to have developed adaptively (responsively); nevertheless, they seem to have no use; and yet they have not handicapped me to such an extent as to prevent my survival to this date.

# CHECK-AREAS AS CONTROLS IN LAND USE

By Professor HERBERT C. HANSON
DIRECTOR OF THE NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

MUCH has been written and said about the depletion of our natural resources. The soil has been mined, the top-soil has been washed or blown away, soluble salts in the soil have been leached out, native plants and animals have been destroyed, streams have been polluted. Statements regarding the extent of the losses have been based largely upon memory of former conditions not upon accurate records. Losses have been so great that agreement is general that waste must be stopped. It would have been more scientific, however, to have planned so that to-day there would be better evidence such as measurements, photographs, descriptions, and, best of all, preserved areas, of former conditions. Had there been such areas available, as standards or checks, to which land under various uses could be compared, misuses of land as we see on all sides to-day might not have resulted.

The investigator or demonstrator usually begins a new task without giving much thought to the soundness of the procedures to be used. He adopts the methods that are in current use and does not give adequate attention to the selection of methods that will yield results which can be readily and directly interpreted. This neglect may be due to lack of emphasis on planning in the literature. Laboratory manuals and papers on methods describe specific procedures in detail but have given little attention to the general design of investigations. But, as is pointed out by Fisher:[1]

> If the design of an experiment is faulty, any method of interpretation which makes it out to be decisive must be faulty too. It is true that there are a great many experimental procedures which are well designed in that they may lead to decisive conclusions, but on other occasions may fail to do so; in such cases, if decisive conclusions are in fact drawn when they are unjustified, we may say that the fault is wholly in the interpretation, not in the design. But the fault of interpretation, even in these cases, lies in overlooking the characteristic features of the design which lead to the result being sometimes inconclusive or conclusive on some questions, but not on all. To understand correctly the one aspect of the problem is to understand the other.

In land utilization programs and in ecological investigations in general there has been less attention paid to the soundness of the plan or design, if one existed at all, than in laboratory and field plot experimentation. But careful designing is needed as much, if not more, in the former fields because of the intricacies of the problems involved. In both of them the relevant and irrelevant factors are extremely difficult to determine, partly because of inherent complexities in the problems themselves and partly because of economic and social interrelationships. One of the most important parts of a plan in land management is a standard or norm or check to which various uses can be compared. In temperature measurements we automatically use standards as zero for cold, or 100° F. for hot. In linear or areal measurements or in weights there are graduated scales; and in many materials definite standards have been established. But in land use there is no adequate standard. The best standard would be areas in their primeval condition, as man found them before alteration with axe or plow or both. The availability of such check areas, now, would permit us to *measure* the losses of top-soil by erosion, the leaching of mineral salts in

[1] R. A. Fisher, "The Design of Experiments," 252 pp. Oliver and Boyd, Edinburgh, 1935.

the soil, the losses in organic matter, alterations in soil structure, the influence of plants and animals, etc.

A number of ecologists have failed to emphasize sufficiently the need for undisturbed areas. Tansley and Chipp[2] state in regard to methods of studying the effects of human activity on vegetation:

> In this field it is obvious that we can lay down no special technique which should be followed. Experiments are being made everywhere and on every scale by human activity in the exploitation of vegetation. Controls are furnished by areas which have not been interfered with. Careful and continuous comparative observation of differently treated areas, or of different types as they naturally occur, is often all that is necessary for the broad solution of practical problems.

This procedure is definitely inadequate because areas which have not been interfered with are extremely scarce, if present at all, in some regions, as the prairies and plains of the United States. While comparison of differently treated areas yields valuable information it is difficult to fully evaluate it unless data from controls or check areas are available.

F. E. Clements wrote that areas are available in which the original relations of the dominant species obtain, especially in grasslands. By using such areas as standards for comparison, practically all degrees of change may be evaluated objectively and the task of interpretation facilitated. He also stated that trackways and roadways furnish favorable sites for securing evidence as to the course of modification and the manner of control of grassland that can not be matched elsewhere.

In many places, however, rights-of-way are unsuitable because they have a layer of cinders over the surface and the soil conditions are modified, and roadsides are

[2] A. G. Tansley and T. F. Chipp, "Aims and Methods in the Study of Vegetation," 383 pp. London, 1926.

—*Photograph by E. O. Wooton*

GRAMA GRASS, CACTI AND SHRUBS

DESERT GRASSLAND AFTER FIVE YEARS OF PROTECTION, IN ORGAN MOUNTAINS, NEW MEXICO.

HOW MUCH OF THIS EROSION IS DUE TO OVERGRAZING?

NOTE NUMEROUS CATTLE TRAILS ON BANKS. CEDARS GROWING ON NORTH SIDE OF BUTTE. GRASSES ARE CHIEFLY WESTERN WHEATGRASS AND BLUE GRAMA. BADLANDS NEAR MEDORA, NORTH DAKOTA.

usually more or less modified by erosion, grazing, drifting of snow or soil, etc. Professor V. E. Shelford[3] and many others have for years been showing the necessity for adequate controls in the form of undisturbed areas, of sufficient size so that natural processes may operate. Pough[4] wrote:

> The greatest handicap under which ecologists and botanists who are trying to solve some of the present problems resulting from land misuse are laboring is the scarcity of areas that man has not disturbed, as only in these can some idea of the original plant and animal association be obtained. It is to the original climax communities of plants and animals that we must go to observe nature in a state of maximum stability, and it is toward the restoration of as close an approximation of these communities as is possible that we must go if we are to insure permanent productivity of the land on which man's continued tenure of it depends. Man's utilization of land involves a shift to different species, and here management is necessary, but a management that utilizes the same fundamental balancing factors that operate automatically in a primitive area.
>
> Let us not be so short-sighted as to fail to profit from past mistakes, in not preserving a study area in undisturbed state in each great biotic region of the country. It is not yet too late to save a few, and far from being a luxury, it may be one of the wisest investments that the country has ever made—natural yardsticks to measure man's land management by. (p. 1078.)

Walter Taylor[5] has been properly emphasizing the need for natural areas as standards to serve in land utilization:

> Mr. R. D. Forbes, Director of the Allegheny Forest Experiment Station, writing in *American Forests*, February, 1934, says that "999 acres of forest land out of a thousand in the territory of the Allegheny Forest Experiment Station have been cut over. The thousandth is virgin timber. The thousandth acre will repay careful

[3] V. E. Shelford, "The Importance of Natural Areas to Biology and Agriculture." In "The Naturalists' Guide to the Americas," pp. 13–14, 1926.

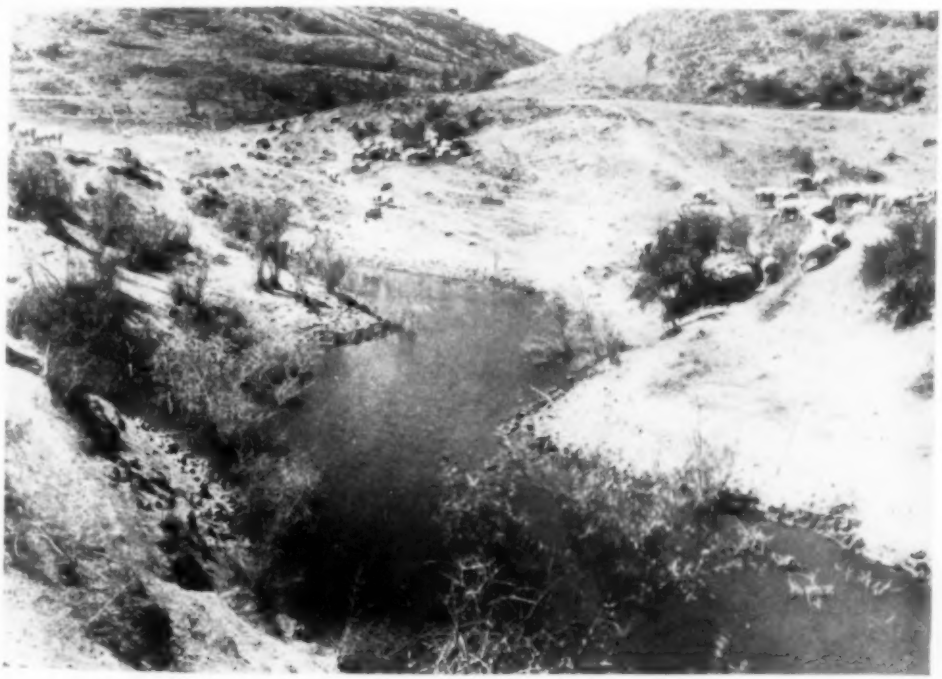
[4] *Jour. Forestry*, 3: 1077–1078, 1936.

[5] W. P. Taylor, *Ecology*, 15: 328–329, 1934.

study." He goes on to point out that on the 999 acres nature's record has been often hopelessly obscured by the heavy hand of man and by fire. In the Southwest where so great a proportion of the land is given over to grazing by live stock, biologists find that it is very difficult to find any land at all under natural conditions. In some localities, over-grazed over a vast extent of country, there is no thousandth acre. This means that there *is no norm* with which to compare the vegetation, animal life, and the soil, as they now appear. One may interview old-timers and get from them valuable hints as to the early condition of the country, its soils, streams, grasses, brush, trees, and wild life—but conclusive demonstration is lacking. The existing situation emphasizes in no uncertain terms the need for saving sample tracts in all important types under as nearly as possible original conditions to serve as a guide for present practice. Disturbance of original conditions is inevitable, under the best administrative regulation, but if areas showing natural conditions were available for observation, the administrator and his scientific advisers would be able to determine just how far management could safely go in modifying the original conditions in the process of grazing or other land use.

The writer can add to Taylor's testimony that in the northern Great Plains the thousandth acre has all but disappeared. During the past few years the author has been studying the characteristics of grassland types, especially in relation to soil characters. One of the chief difficulties has been to find samples of grassland that still possess characteristics not dominated by influence of overgrazing, plowing or other man-made disturbance. The area immediately surrounding the buildings in Wind Cave National Park in South Dakota is one of the extremely rare places where good grassland can be studied. It appears to have been grazed only occasionally by a few horses for many years.

It is too haphazard to place trust in finding field-corners, railroad rights-of-way, cemeteries, etc., which can be used as controls by which to measure land use. Definite provision must be made



VEGETATION AND SOIL

BEING DESTROYED BY OVERGRAZING BY SHEEP AROUND A WATERHOLE. LITTLE IS LEFT OF THE ORIGINAL VEGETATION ON THIS RANGE. BADLANDS NEAR MEDORA, NORTH DAKOTA.

for setting aside areas of large enough size in the major biotic communities so that the intimately interrelated functions of plants and animals may have full scope to operate under the influence of all environmental conditions. The National Park Service and the Forest Service have made a start. Undisturbed areas under their control can be used as check areas by which to measure land use in the surrounding territory, where climatic, soil and topographic conditions are similar. Such areas, however, are inadequate both in number, size and distribution. Many additional land-use controls are needed. Every experiment station, including the state agricultural experiment stations and their substations, should provide for a sufficient number. Every program of land utilization must include such areas in order that the effectiveness of the program may be adequately measured.

Professor S. A. Graham in a recent statement summarized values of such areas and suggestions regarding their administration as follows:

> In brief, it appears desirable that natural areas of sufficient size to include the cruising radius of the most motile non-migratory animals be set up in the various geological areas; that these areas should include some of the few remaining virgin lands, as well as devastated lands, the natural recovery of which should be recorded; that provision should be made for the protection of these areas from the influence of man, and in most instances, from fire; that provision be made for keeping, as a routine, continuous records of meteorological and ecological conditions by the research organization most closely associated administratively with each area; that research by cooperating organizations and individuals be encouraged, but that each project be scrutinized by a competent board to

DROUGHT COMBINED WITH GRASSHOPPERS

DESTROYED ALL FORAGE GROWTH IN WIDE AREAS OF SOUTHWESTERN NORTH DAKOTA IN 1936. NOTE PILES OF GRASS STEMS, CUT OFF BY GRASSHOPPERS, AND WASHED INTO THIS VALLEY BY A TORRENTIAL RAIN, VERY LITTLE OF WHICH PENETRATED THE DRY SOIL. CHECK-AREAS ARE NEEDED TO FURNISH INFORMATION TO SHOW HOW TO WITHSTAND SUCH CLIMATIC AND BIOTIC FORCES. NEAR MEDORA, NORTH DAKOTA.

—*Photograph by V. T. Heidenreich*

THE AREA ON THE LEFT HAS BEEN PROTECTED FROM WILD HORSES FOR TWO SEASONS. NEAR TOPPENISH, WASHINGTON.

determine its probable effects so that any that endanger natural conditions may be rejected. That any administrative developments such as necessary roads or trails be located and constructed in such a manner as to cause a minimum of disturbance; that public access to the areas should be limited to foot trails from camps located on or near the boundary. Such recreational facilities should not, however, be regarded as the primary function, but rather as a means of protection from the results of the undue pressure to open the areas to the public that would almost certainly be brought to bear if the public were entirely excluded. The scientific results that might be expected to come from the establishment and study of these lands would be both academic and practical. In due course of time the laws governing the interaction of living things would become apparent, and the application of the fundamental principles thus disclosed would lead to wiser and more effective use of our natural resources than at present.

It appears desirable, and perhaps necessary, at this time to describe the need for check-areas in some specific land-use problems. The selection of problems was limited largely to those presented in recent literature; others, of probably greater importance, might have been selected.

### Control of Insect Pests

In understanding conditions which most favor pests a knowledge of their original habitat is often very important and will save years of work on the part of investigators. For example the chinch bug was originally found on grasses in waste places along the coast of the Carolinas. Rainy, hot seasons similar to those found in the original area are favorable to the chinch bug. Knowledge of the climate and other conditions in the original habitat would have saved much useless speculation and misinterpretation.[6]

Much remains to be learned about grasshoppers, especially in regard to the relationship of breeding habits and building up of numbers into plague proportions to types of grasslands and grazing conditions. Treherne and Buckell re-

[6] V. E. Shelford, *loc. cit.*, p. 14.

ported that in British Columbia the most injurious species of grasshoppers, as *Camnula pellucida*, prefer to lay their eggs in overgrazed, open, parched, low-grassed areas rather than in ungrazed or lightly grazed areas of tall bunchgrass (*Agropyron tenerum*). In North Dakota Professor J. A. Munro found "that fields of succulent crops for food and adjacent sod land for egg laying offer more favorable conditions for grasshoppers than existed before the native sod was disturbed by agriculture." Check-areas of native grassland are needed to secure information that is essential for the control of grasshopper infestations, which in some years destroy 50 per cent. and more of the vegetation in parts of the Northern Great Plains. Ungrazed areas would serve as adequate standards to which lightly grazed, heavily grazed, plowed and other areas could be compared, and the effects of grasshoppers more definitely measured.

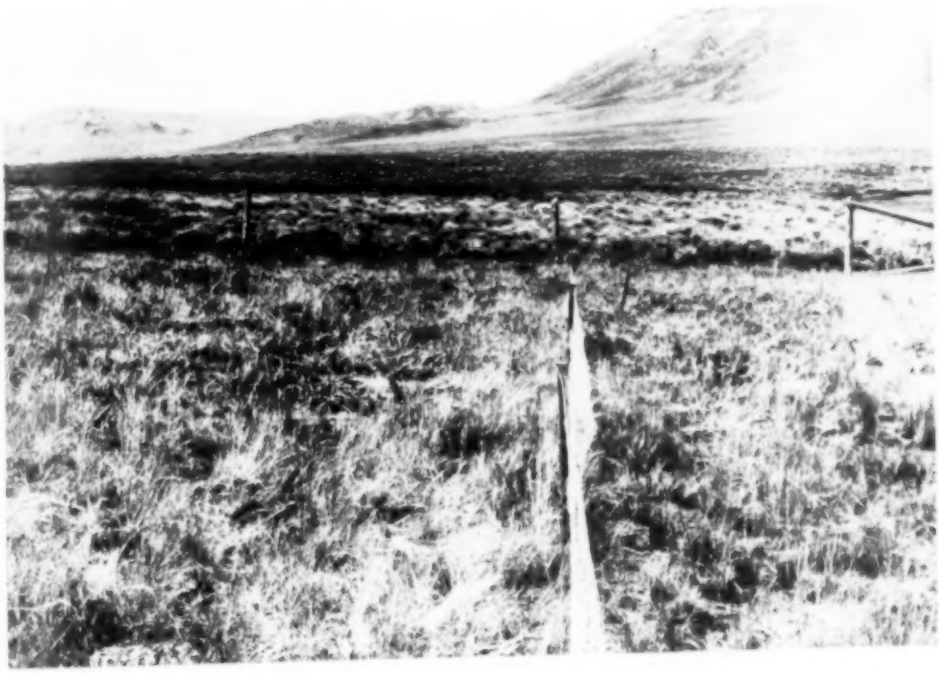
There are numerous insect pests on crop plants, as the Hessian fly, wireworms, false wireworm and army cutworm, some of which were present in our grasslands before cultivation. The natural checks on their increase were parasites, rodents, birds, etc. Undisturbed pieces of grassland to-day would serve as reservoirs of knowledge regarding natural checks, breeding areas for these control organisms and sources from which parasites might be secured for increase. The destruction of all natural grassland areas is possibly leading to the destruction of many unknown natural control organisms. Since insect infestations appear to be increasing in severity and number man will be compelled, if he is to remain supreme, to use all possible resources in controlling them. No longer can he neglect to furnish the opportunities, provided by undisturbed natural areas, to learn facts that are essential to man's progress and mastery.

### Control of Rodents and Carnivores

There appears to be little doubt but that some campaigns for the eradication of some rodents and carnivores have been based upon inadequate knowledge of the role of the animal attacked. There is no question, of course, about the need for destroying the Norwegian rat, plague-carrying rodents and others whose destructiveness is proven beyond doubt. But when there is doubt that the harm wrought by an animal may be balanced, or even more than balanced, by the good it does, then attempted eradication of the animal should be delayed until accurate information is secured. Once the animal is decimated in numbers there may be great difficulty in bringing it back. One of the best ways to evaluate the effects of various kinds of animals is by means of natural areas, which must be of sufficient size so the animals can act naturally. Although bounties are given in some states for the destruction of the coyote, O. J. Murie,[7] of the Biological Survey, concluded on the basis of a 4-year study of 714 fecal samples that "the fur value of the coyote, the potential value of its beneficial habits, the fact that the animal is intrinsically interesting and has a scientific value, and what may be termed an inspirational value, however much derided, can be given considerable weight. After all, the wildlife question must resolve itself into sharing the values of the various species among the complex group of participants in the out-of-door and wilderness wealth, with fairness to all groups. Under such considerations with possible local exceptions, the coyote deserves to remain a part of the Jackson Hole fauna, with only a minimum of control, and that only in the case of unusual local situations."

Taylor, Vorhies and Lister found that jack rabbits in Arizona were more numer-

[7] U. S. Dept. Agric. Cir. 362, pp. 23–24, 1935.



IS THE CLIMAX VEGETATION HERE SAGEBRUSH OR GRASS?

THE SAGEBRUSH ON THE AREA IN THE FOREGROUND WAS BURNED AND THEN PROTECTED FROM CATTLE, AND THE AREA IN THE LEFT FOREGROUND WAS PROTECTED IN ADDITION FROM RODENTS. LARAMIE RIVER VALLEY, COLORADO.

THE RESULTS OF OVERGRAZING

OVERGRAZING STARTED THE DEVASTATION BY WIND ON THIS SANDY LAND NEAR MCLEOD, NORTH DAKOTA. AREAS OF UNDISTURBED VEGETATION ARE ESPECIALLY NEEDED AS MEASURING STICKS FOR LAND USE IN PROBLEM AREAS AS THIS ONE. COMPARE WITH THE NEXT PICTURE.

ARE THE TREES CLIMAX HERE?

BUR OAKS AND SANDGRASS IN A PARTIALLY PROTECTED AREA IN SAND HILLS NEAR MCLEOD, NORTH DAKOTA.

ous on overgrazed grassland than on undergrazed or lightly grazed areas. The effects of overgrazing are seen not only in the increase in weeds and annual grasses but also in animal "weeds." In Oklahoma, Phillips showed that jack rabbits, ground squirrels, pocket gophers and deermice were more numerous on moderately overgrazed grasslands than on undisturbed ones, but cottontails and cotton rats were more numerous on the latter. A rodent may be more injurious than beneficial in some areas but wholly beneficial in others. According to W. L. Burnett in eastern Colorado the striped ground squirrel is injurious, but in the foothills it is valuable because it destroys injurious insects. In regard to the Wyoming ground squirrel Burnett emphasized the need for securing as complete knowledge as possible of its "intricate relationship" to the environment, its food habits, effects on native and cultivated plants and the effects of wet and dry seasons upon fecundity. In order to secure comprehensive knowledge on these subjects check-areas left in natural condition are essential. Vorhies and Taylor[8] in the following quotation have stated the importance of these check-areas to land use so clearly that it is difficult to understand how the provision for adequate control areas can be neglected by any one connected with the formulation of land-use plans.

> We feel that in any bio-ecological problem, involving the plants, animals, soil, and climate of particular areas, it is desirable and often essential to have control areas of large size, *i.e.*, several hundred or preferably several thousand acres, under natural conditions, to compare with areas subject to various degrees of modification by man. . . . In the absence of such areas the answers will lack something in definiteness and conclusiveness. Among the problems to the solu-

[8] C. T. Vorhies and W. P. Taylor, *Ariz. Agric. Exp. Sta. Tech. Bul.*, No. 49, 1933.

tion of which large-sized control areas might be expected to contribute are: life histories, soil relations, and food habits of native animals (rodents, birds, insects, etc.); most productive management of range; range rehabilitation; carrying capacity of the range for livestock, game and native rodents; game problems; and erosion on range lands [p. 475].

It is man's job to understand the balance (of nature) well enough to be sure when he changes it, that the new arrangement will be to his advantage. The fact that man as yet understands very little of the natural world is an excellent argument that he should be cautious in upsetting nature's arrangements [pp. 575–576].

The best control program (for predators, rodents, etc.) is that which interferes least with the orderly relationship of natural species, but which at the same time helps to assure success to the agriculture, range management and forestry on which man depends for his own existence [p. 576].

### Soil Management

Wise use of the soil is dependent upon as complete information as can be secured regarding many complex subjects, such as; composition of the soil, its development, biological and physical processes occurring at various depths, interrelationships of different kinds of soil with all sorts of plants and animals from microscopic forms to trees and mammals, climatic influences and others. Control of run-off and erosion, rotation of crops, irrigation, drainage, maximum use of soil moisture, improvement and maintenance of soil fertility are dependent upon comprehensive knowledge of these subjects. Soil depletion has been serious in the United States partly because land users and planners have neglected known facts and partly because the foundation of knowledge has not been adequate to support the great superstructure of scientific land utilization.

Land planning for improvement and use is handicapped in many places by the lack of scientific knowledge of virgin con-

*—Photograph by L. D. Love*

SOUTHERN LIMIT OF LOBLOLLY PINE IN THE VICINITY OF NEW ORLEANS

THE INTRICATE INTERRELATIONSHIPS OF PRAIRIE, FOREST AND ANNUAL FIRES REQUIRE DATA FROM PROTECTED NATURAL AREAS FOR THEIR SOLUTION.

RED AND JACK PINES, PAPER BIRCH AND UNDERGROWTH OF HAZEL

IN ITASCA STATE PARK, MINNESOTA. FULLY PROTECTED AREAS ARE NECESSARY TO DETERMINE THE COURSE AND RATE OF NATURAL PROCESSES AS COMPETITION BETWEEN SPECIES, SOIL CHANGES, AND INTERRELATIONSHIPS OF PLANTS AND ANIMALS.

PINE RIDGE COUNTRY NEAR CHADRON, NEBRASKA

WHERE THE WESTERN YELLOW PINES AND EASTERN DECIDUOUS FOREST MEET IN THE PLAINS GRASSLAND. THE RESOURCES THAT EACH OF THESE CLIMAXES CAN PROVIDE ARE KNOWN ONLY IN SMALL PART.

ditions. In many places no areas are left in which the original grass or forest remains. The axe and plow, too often followed by disastrous water or wind erosion, have so changed original soil conditions that dependence is placed for knowledge concerning them on descriptions in historical accounts of explorers and in novels, such as the following from "Vandemark's Folly" by Quick.

> The plow itself was long, low, and yacht-like in form; a curved blade of polished steel. The plowman walked behind it in a clean new path, sheared as smooth as a concrete pavement, with not a lump of crumbled earth under his feet—a cool, moist, black path of richness. The furrow slice was a long, almost unbroken ribbon of turf, each one laid smoothly against the former strand, and under it lay crumpled and crushed the layer of grass and flowers. The plow point was long and tapering, like the prow of a clipper, and ran far out under the beam, and above it was the rolling colter, a circular blade of steel, which cut the edge of the furrow as cleanly as cheese. The lay of the plow, filed sharp at every round, lay flat, and clove the slice neatly from the bosom of earth where it had lain from the beginning of time. As the team steadily pulled the machine along, I heard a curious thrilling sound as the knife went through the roots, a sort of murmuring as of protest at this violation—and once in a while, the whole engine, and the arms of the plowman also, felt a jar, like that of a ship striking a hidden rock, as the share cut through a red-root—a stout root of wood, like red cedar or mahogany, sometimes as large as one's arm, topped with a clump of tough twigs with clusters of pretty white blossoms [p. 28].

How much better it would be to have samples of land preserved as much as possible, in their original conditions of soil, vegetation and animal life! In some places the setting aside of such primeval check-areas may still be possible. In other places the next best thing should be done, namely, establishment in each important land region of the best check-areas that are available to use as controls in accumulating sufficient information for scientific land use.

LAND USE IN FARMING REGIONS

IS USUALLY NOT FULLY SCIENTIFIC BECAUSE STANDARDS OF COMPARISON IN THE FORM OF NATURAL AREAS HAVE NOT BEEN SET ASIDE. NEAR MINERAL POINT, WISCONSIN.

Taylor[9] points out that soil fertility may be influenced more by soil animals than is realized, in such activities as accumulation of animal bodies or parts and

[9] W. P. Taylor, *Ecology*, 16: 127–136, 1935.

A FOREST IN ROCKY MOUNTAIN NATIONAL PARK

LOOKING DOWN UPON SPRUCES AND FIRS FROM ABOVE TIMBER LINE IN ROCKY MOUNTAIN NATIONAL PARK, COLORADO. ACTIVE SUPPORT IS NEEDED FOR THE NATIONAL PARK SERVICE TO CONTINUE PROTECTING AREAS SUCH AS THIS IN THEIR NATURAL CONDITION.

food and nesting materials, burrow digging, intermixing soil, dam building and flooding, etc. In a footnote on page 128 he quotes J. F. Breazeale, soils-specialist of the U. S. Bureau of Plant Industry and the University of Arizona, as follows:

> Personally I have never seen a poor or unproductive soil which contained an abundant fauna. I am daily getting more and more of the opinion that results which we get with fertilizers are indirect, that is, we fertilize the soil flora and probably the fauna, and not necessarily the crop. There is a weak link in every chain and in many an unproductive soil the absence of fauna may be the weak link. Animals certainly bring life and vitamin-like substances into the soil.

In recent years soil has started blowing from fields that have not been subjected to serious wind erosion during the previous 20 to 40 years of cultivation. It has been thought that continuous cultivation, accompanied in the last few years by drought, has destroyed the humus, or other binding properties, added to the soil by roots and soil organisms over centuries of time. The crumb structure broke down to single grains, giving the wind a chance to carry the soil away, grinding down soil in adjacent fields to similar structure as the dust clouds swept across the country-side. Check-areas, in their original condition, would aid in determining causes and control for the great increase in soil blowing in the prairies and plains. In too many places the best that can be done, now, is to provide such check-areas for securing information as a basis for scientific land-use in the future.

Soil develops under the influence of the character of the parent material, the climate and the plants and animals living in and on it. Comprehensive knowledge of a soil requires thorough appraisal of the influence of each of these factors. If the native fauna and flora are de-

EVEN AT EXPERIMENT STATIONS

THE USE OF NATURAL AREAS AS CONTROLS HAS BEEN NEGLECTED. EDGELEY, NORTH DAKOTA.

stroyed, as by plowing, does the soil gradually become depleted? This question is difficult to answer unless check-areas in the form of original conditions can be used for comparison. In a recent study Hanson and Whitman attempted to describe some of the relationships between type of grassland cover to characteristics of the soil, a subject of fundamental importance in soil and range survey work, in range management, in soil development and in plant succession. One of the chief difficulties encountered in this study was to find areas of grassland where direct plant-soil relationships, unmodified by injury from grazing, plowing or other agency, were still present. Such areas were extremely scarce in the Northern Great Plains. Usually the relationship of the vegetation was not directly with the soil but with disturbing agencies. Undisturbed check-areas are essential for such studies. Tansley in a recent paper raised some fundamental questions regarding vegetation-soil relationships, which can only be answered by data from studies on undisturbed natural areas. Scientific land use requires answers to such questions as Tansley raises:

> It is a simple and attractive idea that development of the soil profile runs *pari passu* with development of the vegetation it bears, and that consequently the mature climatic soil type corresponds and co-exists with the climatic climax community. *It is, however, quite premature and probably untrue to make any such general assertion.* It may very well be that in particular cases such a correspondence actually exists. But on the other hand, even when profile development under the influence of climate is perfectly normal and regular, the climatic climax community may establish itself long before the soil is mature, and may not be substantially altered by the later stages of profile maturation. Again a climatic climax may establish itself on a soil which is *kept immature* by geological and physiographic causes, as on a steep slope. And finally it is now generally agreed by pedologists that some rocks, owing to the simplicity of their composition, produce

soils which can *never* form the normal climatic mature profile, and these may or may not bear the typical climatic climax vegetation.

Weaver and Flory[10] have demonstrated the value of native grassland in determining the effects of cropping to corn for three years near Lincoln, Nebraska. They found that the soil in the cornfield became heavier per unit of volume, decreased 12 per cent. in porosity, and its rate of percolation was retarded 42 per cent. or more, causing greater run-off and erosion. Mean temperatures averaged 3.9° F. lower at night and 2.7° lower in the daytime in the prairie than in the field. In some very hot weeks the maximum temperature was up to 11° F. higher in the field. The soil temperatures were lower, relative humidities higher, and evaporation losses lower in the prairie; so the grassland exerted considerable stabilizing influence in tempering extremes.

The applications of lessons learned from a careful study of vegetation are manifold. In this period of the reclaiming of marginal lands, of planning great projects to ameliorate erosion, of developing scientific plans for land utilization, and of definite planning to establish cropping systems best calculated to produce economic returns from the different types of soil, we may profitably consider the natural environment. Not until the native environment in its relations to water, humidity, temperature fluctuations, and other critical factors of both air and soil has been compared with that of overgrazed and cropped areas will it be known how widely we are departing from Nature's plan of a stable environment.

Again the conclusion is inescapable that undisturbed natural areas are needed as controls in scientific land use.

### Forest and Range Management

Foresters have recognized, perhaps more than any other group, the need for control areas. An important step was made in 1930 when the following National Forest regulations went into effect:

The forester shall determine, define and permanently record a series of areas of national forest land to be known as experimental forests sufficient in number and extent adequately to provide for the experimental work necessary as a basis for forest production or forest and range production in each forest region, these areas to be dedicated to and used for research; also where necessary a supplemental series of areas for range investigations to be known as experimental ranges; and a series to be known as natural areas sufficient in number and extent adequately to illustrate or typify virgin conditions of forest or range growth in each forest or range region, to be retained in a virgin or unmodified condition for purposes of science, research and education; and a series of areas to be known as primitive areas within which will be maintained primitive conditions of environment, transportaton, habitation and subsistence, with a view to conserving the value of such areas for purposes of public education and recreation. Within any areas so designated, except for permanent improvements needed in experimental forests and ranges, no occupancy under special use permit shall be allowed, or the construction of permanent improvements by any public agency be permitted, except as authorized by the forester or the secretary.[11]

In January, 1937, according to L. S. Bean, acting chief of the Division of Recreation and Lands of the U. S. Forest Service, there were 67 *primitive areas*, varying in size from 5,000 to 1,087,744 acres; 26 of which are *roadless areas* and 41 wild areas in the National Forests. The chief difference between these areas is in size; the minimum size of the former is 100,000 acres for forest and 500,000 acres for desert. *Natural areas*, called *botanical areas* in the new classification, include 37,066 acres in 29 areas. They differ from primitive areas chiefly in being smaller or in showing past disturbances of the vegetation. There were on this date 50 *experimental forest and range areas* comprising 583,849 acres. A number of foresters have described the needs for these check areas. Dr. C. F. Korstian wrote in 1926 that "so far as the forester is concerned, the main reason for preserving natural areas is to retain a standard of accomplishment of nature

[10] J. E. Weaver and E. L. Flory, *Ecology*, 15: 333–347, 1934.

[11] L. F. Kneipp, *Science*, 72: 560–561, 1930.

alone, to serve as a guide by which the correctness of the forester's efforts to improve on nature may be gauged." Ashe in 1926 presented the uses of check-areas in greater detail:

> The study of the unmodified areas, in connection with those which are modified, will indicate the extent to which it will be possible to deviate from the normal and yet retain the equilibrium necessary for maintaining the factors of the locality. Such studies will determine whether it will be possible economically to replace one species by another, whether it will be advantageous to substitute a pure coniferous stand for one of mixed hardwoods, or if not, as to what proportion of the stand the conifers can occupy. The natural areas must in large measure serve as the means of developing our silviculture; their elimination from exploitation and their preservation is essential to that end.

### Management of Marshes, Lakes and Other Bodies of Water

As indicated by Adams, public planning of water resources should be based primarily upon social values, rather than solely upon economic values; public interest should be dominating; and scientific data are essential to serve as a foundation. Some of the primary uses of marsh and water areas are: supplies for drinking water, transportation, recreation, habitat for wild animals and flood and drainage control. Leopold has raised a number of questions regarding the management of marshes adjacent to the Wisconsin River in the vicinity of Wisconsin Rapids, Wis. Some of these questions are: How shall dam-building to raise water levels be divided between engineers and beavers? What is the relationship between cattails, ducks and muskrats? Do mowed or unmowed hay meadows favor prairie chickens? What are relationships between deer and tamarack, birch and grouse? These questions can

INSTEAD OF THE MORE USUAL V-SHAPED ERODING DRAW
LAND-USE PLANNING HERE HAS PERMITTED THE BEAVERS TO MAKE A WIDE, WATER-FILLED VALLEY. IN WESTERN NORTH DAKOTA NEAR KILDEER.

not be readily answered, especially since economic forces and public sentiment have played and will probably continue to play important roles. The answers to these questions would be more scientific, and probably more readily accepted by economic forces, if they could be based upon data secured from study of marshes which had been left in their natural condition. Since such areas are not available now, it appears that it would be sensible to set aside well-selected areas of sufficient size to use as check-areas for future planning and to measure present uses. It would be economical in the end to have such areas because it would save much experimentation by the trial-and-error method and it would give land planners more facts to use in designing their work and interpreting results.

Pollution of streams and lakes, drainage, irrigation, erection of dams, construction of recreational facilities, etc., have modified conditions in so many bodies of water and marshes that original conditions have been almost entirely destroyed. Numerous plants and animals and the environments in which they live have thus been lost to men and women, and saddest of all, to children, at a time when there is more leisure for their enjoyment. In fact, these resources, which have been lost in large measure, may be considered vital in planning for future land use, if the chief basis is social values. Everything should be done to restore as much as possible these wasted aquatic resources. Natural areas of large enough size are needed first of all as demonstrations of the resources that nature can provide for a well-rounded program of land use.

## Conclusion

Scientific land use requires as careful planning as is humanly possible. The plans should be thoroughly studied from all angles. All sources should be tapped for relevant data. Much land planning is unavoidably experimental. The recent emphasis on design and interpretation in biological experiments applies with even greater weight to work in land use. An important source of basic information, that has been neglected in the past, is land in natural condition used as checks, controls or standards by which land may be measured. Planning, if it is to be as serviceable to humanity as possible, must provide these check-areas, even though land in original condition is no longer available. Carefully selected tracts must be set aside as soon as possible in each of the natural land-use areas of the United States by the various state and federal agencies concerned with land-use problems. The Forest Service and National Park Service have taken the lead; other federal and state agencies must follow if land utilization is to be based as fully as possible upon science.

# FOSSIL FISH LOCALITIES IN THE GREEN RIVER EOCENE OF WYOMING

By CURTIS J. HESSE

ASSISTANT CURATOR OF THE MUSEUM OF PALEONTOLOGY, AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS

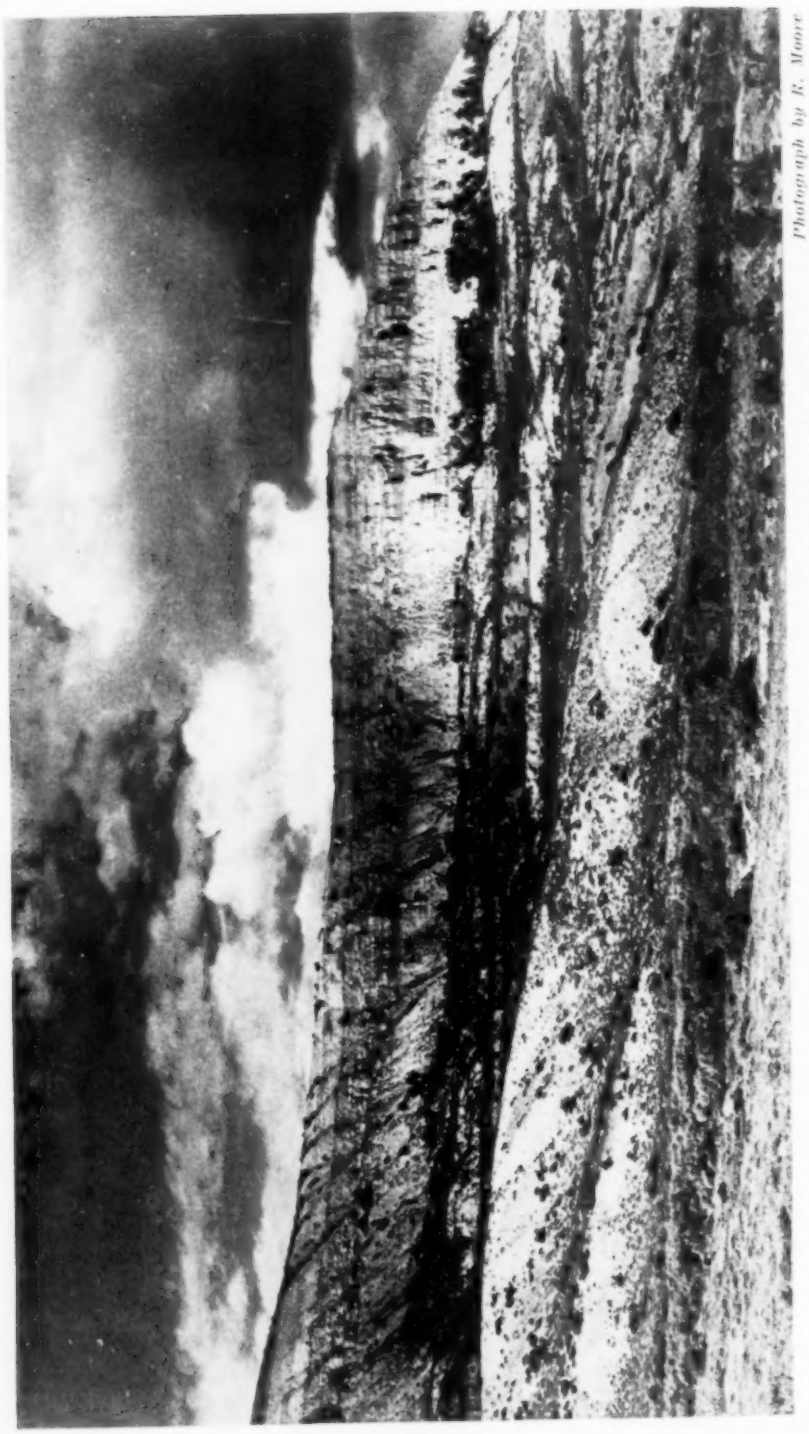
FEW museums in the world, certainly none of the larger ones, are without specimens of the fossil fishes from the Green River shales of southwest Wyoming. These are prize exhibition specimens and no other fossil-bearing formation in North America has produced so many and such characteristic fossils as this great series of lake beds.

So far as can be determined, the first scientific notice of these remarkable fishes was published by Dr. Joseph Leidy in 1856. He described the fossil herring, *Clupea humilis* (now known as *Knightia alta*), from a specimen sent to him by Dr. John Evans. The specimen had been picked up "on the Green River." From that year on, although probably known to local people, the locality received no more attention from scientists. In 1868, when the Union Pacific Railroad was being built through western Wyoming, Green River Station became a place of importance. At the western edge of the town, a long cut was made in the shale bluffs along the river. So many fossil fishes were found that this part of the right-of-way was named "Petrified Fish Cut," and the abundant material brought to the attention of the Hayden Geological Survey.

From the collections made by the Hayden Survey and from donations of local people the first adequate idea of the fauna, as well as of its abundance, was obtained. This collection was described by E. D. Cope in 1870 as a part of the Hayden Survey report of that year. Following this in close order came a series of papers by Cope on this fauna, some duplicating previous papers, others brief notes and appendices in unrelated papers. In this confusing mass of literature over twenty-five species of fishes were described, but no figures were given. From 1877 until the publication of Cope's "Bible" in 1884 nothing more appeared in print. In the "Bible" the entire series was reviewed and most of the species were figured. The list now included thirty species, and possibly more, for many of the locality references were obscure or left out entirely. Since that time few scientific papers have been written on these fishes; but now and then an additional species has been added to the list.

These fossil fishes are so beautifully preserved and so common that one would expect some detailed account of the localities from which they were collected; yet none seems to have been published. Cope, in 1877, speaks of three localities; the "Petrified Fish Cut" west of Green River, a locality "near the mouth of Labarge Creek" which he discovered in 1872, and a third "near the main line of the Wasatch Mountains." From this last locality Mr. H. Schoemaker had forwarded to Cope a collection of fishes, leaves and insects. No mention of the Twin Creek locality was made in these earlier papers. It was discovered between the time of publication of these early papers and the great "Bible," or else this name was given to the locality above cited as "near the main line of the Wasatch Mountains."

The Twin Creek locality has been the source of most of the fishes collected since



*Photograph by R. Moore*

FIG. 1. FISH CLIFFS, ONE MILE NORTH OF FOSSIL, WYOMING.

THIS IS THE TWIN CREEK LOCALITY OF COPE. THE CLIFF IS ABOUT SEVEN HUNDRED FEET HIGH, THE FISH LAYER IS JUST ABOVE THE DARK BAND TOWARD THE TOP.

the 1870's. Here both scientific and commercial collectors have been working since 1880. The main locality is at "Fish Cliffs" (Fig. 1), on the north side of Twin Creek Valley, one mile north of Fossil, Wyoming, a station on the Oregon Short Line Railroad. Other localities have been worked around Fossil, and much material has been obtained, but the preservation of the fishes, at least, is seldom as good as at Fish Cliffs.

The section of Green River shale exposed in Twin Creek Valley is about seven hundred feet thick. Toward the top it grades into a brownish zone, less resistant to weathering, which rounds off the top of most of the bluffs of the more resistant oil shale. The fish layer on Twin Creek is about fifty feet below the top of the main bluffs, in the typical part of the section. It is a bluish-white marl, thin-bedded, brittle and not the higher grade oil shale found throughout this formation. Its total thickness is near one foot, and it is divided into a four-inch and an eight-inch member by a thin seam of oil shale.

The method employed by collectors working out a part of this layer is a simple one. A quarry site is carefully chosen, it must be bounded on either side by "settling cracks" which divide the entire face of the bluffs into units of varying size. The layer itself between the settling cracks must show joint cracks clearly, from two to four feet apart. The large settling cracks determine the size of the quarry, and since there is a slight slope to the bluffs, by starting thirty or thirty-five feet above the layer and removing the shale between the settling cracks, a considerable area of the fish layer is exposed. The over-burden is blasted and moved away by hand. Several layers of fishes are encountered, but they are poorly preserved and rotten. One layer seems to be made up of loose scales.

After the fish layer is cleared of over-burden, the joint cracks prove their value. They enable the collector to raise the stone between them in blocks not too large to handle. Once the slab is raised and resting on saw-horses, a line of thin chisels is driven into one end of the slab to split it in half. No matter how thin the slabs become they are "halved" if possible. Seldom are the fishes found directly on the bedding planes (along which the rock cleaves) but lie between them covered by a thin film of matrix. The "shadow" of dim outline of the vertebrae and caudal fin may be seen, but an experienced eye is much quicker at this than an amateur.

Once specimens are seen, and they are likely to be numerous, the slab is sawed into convenient sizes for handling with as little damage to the material as possible. The commercial collectors carry the slab down off the cliffs and put them in storage, to be worked out during the winter when the inclement weather prevents activity in the quarries. In the preparation of this material the commercial collectors use an ordinary pocket knife with a rounded blade point and sand paper. Most any museum contains specimens of their skilful workmanship.

Seldom has this quarrying been more than a one-man job, the usual rate is one quarry opened and cleared out in the four summer months.

The most common fishes are those of the genus *Diplomystus* (Fig. 2), a small herring. These are from two to twenty inches long, and the five- to seven-inch size sell for one dollar and fifty cents to three dollars. It is often possible to obtain several of these on one slab; as high as twenty-four fishes have been developed on slabs of less than one square yard. The small *Priscacara serrata* (Fig. 3) is the most popular and easily salable of all the types of fishes collected here.

Under the name "Sun Fish," five- to seven-inch specimens bring from two to five dollars. Members of this genus are less common than the Diplomystids, and the smaller sizes tend to occur in "schools." Certain quarries will contain many hundreds of them, while in others they are relatively few. *Pharodus* (Dapedoglossus), a deep-bodied fish with many circumorbital plates, is also fairly common among the larger fishes. Small specimens of this form, twelve to twenty inches long, sell for fifteen to thirty-five dollars; but the still larger specimens run as high as one hundred dollars. The other genera of this fauna are less common, especially the larger sizes. However, every quarry furnishes these in some quantity. The fresh-water sting-ray and the large garpike from these beds are rare. If one specimen of either form is encountered in a quarry, the excavator considers himself lucky. The other elements of the fauna (birds and reptiles) are so rare that probably less than five specimens have been discovered.

The market for these specimens is largely through curio dealers all over North America. Some material is sold to passing tourists and to commercial fossil collectors. Many years ago specimens were sold on the depot platform at Green River, Wyoming. Fifty cents to a dollar and a half covered most of the fishes sold in this manner. Very few specimens are purchased by museums or other scientific institutions. The market is never "flooded," since only a few people are collecting at a time. Many of the specimens are cemented into fireplaces, or used in other decorative ways; a few ultimately find their way into museums.

The most persistent collectors of this material have been Mr. Haddenham, of Kemmerer, Wyoming, and Robert Lee Craig, who is now in retirement. Both these men have worked the Twin Creek exposures for the last forty years. The "Fish Cliffs" are on public lands, and attempts to homestead or purchase the locality have been side-tracked. Apparently it is the intention of the land office to keep the land open so that any one may collect there. It is possible that the area may be made a state park in the future.

Fossil fishes are found scattered throughout the entire Green River

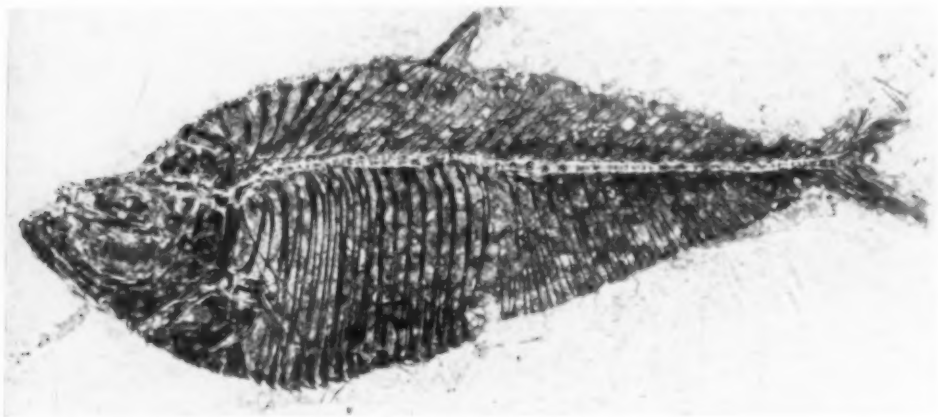


FIG. 2. *DIPLOMYSTUS ANALIS.*

MEMBERS OF THIS GENUS ARE THE MOST COMMON OF ALL FISHES IN THE GREEN RIVER SHALES. THEY RANGE IN SIZE FROM TWO TO TWENTY INCHES; THE ABOVE SPECIMEN IS ABOUT SIX INCHES IN LENGTH.

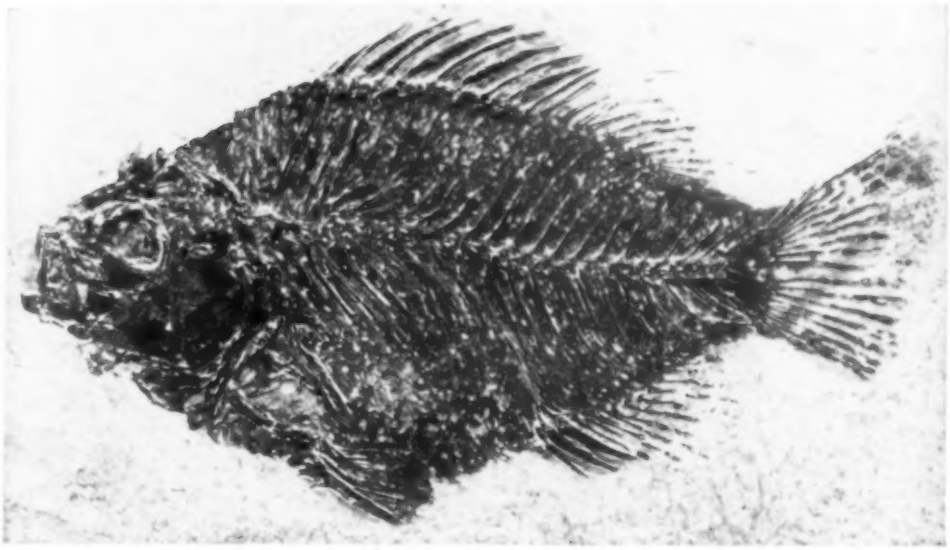


FIG. 3. *PRISCACARA SERRATA*, A CICHLID FISH.
ONE OF SEVEN SPECIES FOUND IN THE GREEN RIVER FORMATION. THESE FISHES RANGE IN SIZE FROM THREE TO TEN INCHES, AND ARE THE MOST SALABLE OF ALL FORMS FOUND THERE.

formation, but so far as known the above localities are the only ones which have produced abundant material. How, then, may the deaths of countless numbers of fishes, at more or less regular intervals, over a great period of time, be accounted for? The sediments of the Green River are, in part, volcanic, but the deposition of this volcanic material was in no sense cataclysmic. There is little to indicate that there were any ash falls, seemingly the volcanic material was more in the nature of dust. The even, laminated deposition of the beds does not suggest that the fishes were suddenly overwhelmed by terriginous matter, such as might occur in times of flood. Nor is there any sign, in the specimens themselves, that might indicate struggling accompanying a violent death.

Bradley, in discussing the varves of the Green River formation, has brought out the high organic content of the sediments of this formation. This organic matter passed through a stage of putrefaction, analogous to the black fetid organic oozes now forming in both fresh- and salt-water lakes. That annual deposits of this organic matter were laid down seems to be proven beyond doubt. Possibly the fishes were killed by the fouling of the water due to dead plankton and algae. Any home aquarist is familiar with the danger of "green water" suddenly turning brown, a change that may take place in a few minutes, killing all the fishes in the tank.

Some such explanation as this seems logical to the writer to account for the Green River fish layer. However, the varves extend throughout the entire two thousand feet of the formation, while the fish layer is only fourteen inches thick, near the top of the section. Nor is that layer seemingly one rich in organic matter derived from the sapropel. Why fish layers are not common in the entire section I am at a loss to explain.

# INSECT GALLS

By CHARLES I. LONG
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INSECT galls, although more common, are so inconspicuous as to be almost as hard to find as honest men. They are odd and often beautiful growths on plants and trees caused by any of a number of tiny insects known collectively, although rather unscientifically, as gallflies. The commonest of these gallflies are gall-wasps (Cynipidae), gall-gnats (Cecidomyiidae) and aphids (Aphidae). Aside from these, certain mites, sawflies, thrips, caterpillars and chalcis flies occasionally cause them.

A typical gall, such as the oak apple, is formed in the following manner: A female gallfly selects a suitable plant and punctures the epidermis of a developing leaf or bud with her ovipositor. In the hole thus made she deposits an egg. Shortly afterward the egg hatches into a minute grub, which starts to feed upon the plant tissues surrounding it. The cells in these tissues become extremely viable, and, increasing rapidly, must of necessity bulge out in one way or another. Soon the grub is completely enveloped by a structure that may be almost any shape and often of considerable beauty.

COMMON OAK APPLE

A TYPICAL GALL, FOUND ON THE LEAVES OF THE RED OAK IN MAY AND JUNE. CAUSED BY THE GALL-WASP *Amphibolips confluentus* HARR.

Within this protective and nutritive prison the larva feeds and grows, sometimes for days, sometimes for weeks or even months, and there is often a definite correlation between the length of the larval stage and the life of the gall. After the period of pupation, the larva, now a matured insect, chews its way to liberty with its saw-like jaws.

This, briefly, is the story, but it has many variations. For instance, not all gallflies have jaws with which to bite their way to freedom, and the means by which they circumvent this handicap is often amazing. In the case of aphids, whose mouths are fitted only for imbibing liquids, the predicament is solved by natural openings in the galls through which the mature bugs can emerge by the simple expedient of walking. A quite different condition obtains among some gall-gnats, whose pupae are provided with spines to function in boring a hole to the surface. The origin of such timely and adequate structures for an emergency occurring only once in the life of the insect is a drama in itself. In still other cases, galls rupture at precisely the time the mature gnats are ready to leave. Without such provisions as these, galls would become lethal chambers for their helpless prisoners. In remarkably few cases, considering that it would seem the

easiest method, the larva eats its way out of the gall and pupates on the ground. One would expect to find mandibled larvae of all helpless gnats doing this instead of waiting until, during metamorphosis, they lose their jaws and become dependent upon the rupture of the gall or the development of pupal spines or some other such makeshift, to provide a means of escape. But then, one has reason to expect many things that never happen.

The origin and evolution of the adaptive cooperation between insect and plant is a problem to stir even the slowest imagination. By what accident was the gall-forming habit first hit upon in the life cycles of such diverse insects as wasps, gnats, aphids and moths? How does it happen that solid, woody galls with no natural outlets are associated with insects having some sort of gnawing apparatus, while those of helpless aphids have natural openings, or accommodatingly form them at the proper time? What causes galls to form in the first place?

The questions of the why and wherefore of a gall's formation have long been matters of conjecture, but the researches of biologists have gradually cleared away much of the fog surrounding them. Some galls presumably are caused by a minute drop of poison injected into the plant by the female insect as she lays her egg. This causes a sudden, rampant growth of the always active cambium and parenchyma cells and a consequent enlargement comparable in some ways with the swelling caused by a mosquito bite or bee sting. Moreover, since each species of gallfly causes a characteristic gall, it has been supposed that this is analogous to the fact that fleas, wasps, bees and other insects produce characteristic swellings on people, the chief difference being that in the case of such stings no egg is present. Evidence to support this theory is found in the fact that all hymenopters (a group including gall-wasps) possess a poison-secreting gland in close proximity with the ovipositor. It would seem, therefore, that the specific stings of the different species of insects might cause equally characteristic galls. It is hard to prove this, however, if for no other reason than the fact that the virus is secreted in such minute quantities that chemical analysis of its composition and effect is almost impossible.

On the other hand, most galls do not begin to form immediately after the egg is laid, but wait until the larva has hatched and begun to feed upon the plant tissues surrounding it. In this case it is doubtful if a poison could be the cause. Moreover, there are plenty of gall-producing insects which do not secrete a poison sting. This indicates that, in such cases at least, it is the movements and secretions of the growing grub, a constantly renewed chemico-frictional stimu-

OAK SEED GALL

ONE OF THE MOST BEAUTIFUL OF OUR NATIVE GALLS, ON THE WHITE OAK IN JUNE. CAUSED BY GALL-WASP *Andricus seminatus* HARR. A COMPACT WAD OF GLISTENING WHITE FIBERS ENVELOPING A GROUP OF SEED-LIKE LARVAL CHAMBERS WITH HARD, STRAW-LIKE WALLS.

POINTED BULLET BALL

A VERY COMMON GALL GROWING SINGLY OR IN CLUSTERS ON THE TWIGS OF THE SWAMP WHITE OAK. IT IS HARD AND WOODY, WITH A LARVAL CAVITY IN THE CENTER CONTAINING A WHITE-SHELLED OVAL STRUCTURE IN WHICH THE LARVA LIVES. CAUSED BY GALL-WASP *Holcaspis duricaria* BASS.

lus that initiates the odd formations we see (but more often do not see) on trees and lesser plants.

It is probable that both of the above explanations are true in their respective cases and that galls are the result of several contributing causes rather than any single one. The second process is known to be true in most instances and is indisputable where the gall-producing insects are definitely known to be devoid of the virus-secreting glands. But there are still other factors that can not be overlooked. For example, some galls do commence to form almost as soon as the egg is deposited, even though no poison is present, and, since the egg swells after being inserted into the plant, its pressure on the surrounding tissues may be the initial stimulus to gall formation. This would not account for the specific differences in galls, however.

The correlation between the structure of the gall and of the insect is understandable on the theory of natural selection, in so far as galls providing no egress to jawless insects would inevitably weed out the failures as they arose; failures, that is to say, in producing open-mouthed galls or pupal structures to cope with the problem of solid galls. It is probable, for instance, that for every species of jawless insect whose life history involves a gall with a natural opening, countless other species have at some time in the geologic past attempted similar ventures with disastrous results. Those which evolved the device of pupal spines doubtless suffered an even greater weeding out. Those galls which are more or less solid, with no natural openings, but which

OAK PETIOLE GALL

A COMMON GALL CAUSED BY THE GALL-WASP *Andricus petiolicola* BASS. THE ILLUSTRATION SHOWS HOW THIS TYPICAL GALL RESULTS FROM THE CONVERSION OF ORDINARY LEAF TISSUE INTO A SOLID, WOODY STRUCTURE CONTAINING MANY LARVAL CHAMBERS.

rupture or disintegrate at the time their jawless gnats are ready to emerge, almost suggest design as an explanation for the opening of prison doors at the crucial moment. Such timing seems too accurate to be accidental. But the answer is to be found in the physiology of a gall. As long as the larval secretion continues, the cells of the plant will be stimulated, but when at pupation these secretions and excretions cease, the plant tissues are no longer stimulated. Their viability quickly wanes and growth ceases altogether, for the sap channels are completely disorganized in a gall. Thus the once abnormally active cells wither and split apart. By this time the gall-gnat larva has completed its metamorphosis, and wakens to find an unimpeded passage into the world of love and sunlight. The evolutionary implication is that selection has been in the direction of adapting the pupal stage to the length of time required for the active gall tissue to disintegrate.

HICKORY LOUSE GALL

CAUSED BY *Phylloxera caryaecaulis* FITCH. A TYPICAL EXAMPLE OF AN OPEN-MOUTHED APHIS GALL. IT IS A DISTORTION OF A BUD.

HICKORY ONION GALL

CAUSED BY THE GALL-GNAT *Cecidomyia holotrica* O. S. ONE OF THE COMMONER GALLS FOUND ON THE LEAVES OF HICKORIES IN MID-SUMMER.

The reason why jawed insects such as gall-wasps produce structures with no natural openings is not so easy to answer, for there would appear to be little advantage gained except, possibly, greater protection from enemies, rain and the rigors of winter. These advantages may be more important than we suppose, however, for it is true that by far the greater number of galls are produced by these mandibled insects, and they are almost always devoid of natural openings.

A surprising feature of many galls is their dissimilarity from the parts of the plant upon which they occur. So great is this that they often appear to be foreign parasitic bodies adhering to a leaf or twig, and not merely modifications of those parts at all. Their appearance is in the nature of a biological caricature, however, for they are disproportions and exaggerations of fundamental parts of the plant, just as moles on human beings are scarcely recognizable modifications of

ordinary tissues. A gall is a leaf gone wrong, a twig that has run amuck, a bud that has defied its destiny.

Most galls are associated with gall-wasps of the large family Cynipidae. These insects rarely exceed a sixteenth of an inch in length, and range in color from red to orange, and from blue to green and black. Their mandibled mouth is fitted for gnawing, and is used to advantage in releasing the imago from its gall. The adult wasps apparently require no food, although they have been known to take a sip of water.

Most gall-wasps prefer oaks where they deposit their eggs in the leaves, bud or stems with a proportionately long ovipositor. The egg has a thread-like appendage called an egg-stalk reaching to the top of the hole apparently functioning as an air tube. The stalk is longer or shorter in proportion to the depth at which the egg lies in the puncture.

FLAT WILLOW GALL

CAUSED BY THE SAWFLY *Nematus desmiodes*. THE LEAVES OF THE SHINY WILLOW ARE OFTEN HEAVILY BURDENED WITH THESE FLAT, SOLID GALLS.

HICKORY CONE GALL

NOT UNLIKE THE ONION GALL IN SHAPE, BUT DEVOID OF THE BROWN PUBESCENCE CHARACTERISTIC OF THAT GALL. AT FIRST IT IS PALE YELLOW, BUT LATER BECOMES RED OR VIVID BEET PURPLE, FINALLY TURNING BROWN AT THE END OF THE SUMMER. CAUSED BY THE GALL-GNAT *Cecidomyia sanguinolenta* O. S.

The minute, delicate gnats of the family Cecidomyiidae also produce galls. These insects sometimes attack annual plants, a departure from the usual habits of gall producers.

A few aphids cause galls which are due, apparently, to the excretions of the mother bug. The gall grows about her, and in it she gives birth to young, instead of laying eggs like ordinary insects.

Parthenogenesis, or virgin birth, is not confined to Christian mysteries, for it is not an uncommon occurrence among gall-producing insects, especially gall-wasps and aphids. In fact, generation after generation of certain species of gall-wasps have been bred under laboratory conditions with never a male appearing. In other species both males and females emerge from galls in the summer. These

BLACKBERRY KNOT GALL

A LARGE, LUMPY, DEEPLY FURROWED MASS OF JUICY PITH WITH MANY FAIR-SIZED LARVAL CHAMBERS, CAUSED BY THE GALL-WASP *Diastrophus nebulosus* O. S. A VERY COMMON GALL, AND ONE OF THE FEW THAT IMPAIR THE VITALITY OF THE PLANT, ALL PARTS ABOVE IT DYING, BUT NOT UNTIL THE GALL ITSELF HAS BECOME BROWN AND WOODY IN THE AUTUMN.

mate, and the females lay their fertilized eggs, causing more galls that remain over the winter. From these eggs only females hatch in the spring. These virgin females nonchalantly lay eggs without ever seeing a male of their kind, for there are none. Moreover, the galls of this asexual generation are totally different from the ordinary ones caused by fertilized females. The unromantic matriarchy is interrupted when the spring brood hatches in the summer, completing the cycle with a generation of both males and females. Sometimes many male-less broods will follow each other before a bisexual one occurs, and when this happens the galls do not differ from one generation to the next until the asexual spell is broken.

Such parthenogenesis seems incredible to people who dogmatize from the doings of mice and men, but among invertebrates it is not an uncommon occurrence. Actually it is not as miraculous as it may appear, for it involves nothing more than the failure of the ripening egg cells to divide the number of their chromosomes in half. Since the ripened eggs contain the full complement of chromosomes instead of only half, as is the case with most animals, there is no need for mating between male and female. Thus the gall-flies solve the problem of asceticism.

More galls occur on oaks than on any other single group of trees. As many as ninety or more have been found on one species alone, and most of them are caused by gall-wasps.

Hickories also are prone to mold their leaves and stems into galls, and do so from spring until autumn. The greater number of these oddities grow upon the leaves, and few of them are of any con-

GRAPEVINE TUBE GALL

A RATHER RARE GALL CAUSED BY THE GALL-GNAT *Cecidomyia viticola* O. S. THE SURPRISINGLY TOUGH EPIDERMIS SURROUNDS A BROWNISH, JUICY AREA, IN THE CENTER OF WHICH IS A MINUTE HOLE CONTAINING AN ALMOST INVISIBLE LARVA.

siderable size. The most conspicuous, though not necessarily the commonest, are those of the aphids, growing as large as a nut upon the stems, or developing into warts upon the leaves, assuming a variety of shapes and colors. A single tree will often produce as many as five or six different kinds of galls and in great profusion. Many of the leaves will be thickly dotted with the strange little growths, and the terminal twigs will be heavily burdened with leathery tumors.

There are more than fifty described kinds of galls on willows. Most of these are formed by gall-gnats, although some are caused by mites and sawflies. They usually occur upon the leaves of the bushy willows.

Many other kinds of trees have their characteristic galls. The basswood grows pallid warts on its leaves, the alder reconstructs its bud, and the honey locust turns its leaves into pods. The pitch pine and balsams modify their terminal twigs, and the cypress contrives miniature pineapples. The dogwood, wild cherry, tulip tree and ash all produce galls freely, as do the maples, poplars and witch hazel. On the other hand, the horse chestnut rarely if ever produces one.

There are scores of plant galls, some of them too small to be noticed, while others are too large to escape the attention of any but the blind. The goldenrods are particularly prone to such deformities, and the bulges on their stems are a common sight on any walk in the fields. Loosestrife is another plant that is commonly galled, and grapes, poison ivy and wild lettuce all have their characteristic tumors. A host of other plants develop galls, but they do so either less commonly or less conspicuously. For instance, a gall is rare on the black-eyed Susan, while the bulge on the false indigo stem, although common, is less often found because it is insignificant and hidden among the foliage. Few galls on annual plants are made by gall-wasps, but many are made by gall-gnats.

The rose family is peculiarly susceptible to the gall impulse, and yet in some regions very few rose-galls can be found. Not only wild roses, but also the blackberry, raspberry and cinquefoil, all members of the same family, produce these structures.

One never knows what is in store for him when he hunts for galls. I thrilled one time with the discovery of what I knew must be a new and rare specimen, for there, hanging from the leaf-stalk of a hickory sapling was a furry growth as large as a lemon, and quite different from anything described in any work on galls I had ever studied. But just as I was about to examine it, it sleepily lifted its head, half opened its beady eyes and flew away. My gall was a little bat!

# FRESH-WATER AQUARIUM FOR MUSEUM USE

By CLIFFORD B. MOORE and FRANK D. KORKOSZ

SPRINGFIELD (MASS.) MUSEUM OF NATURAL HISTORY

SPRINGFIELD, MASSACHUSETTS, a city with a population of 150,000, is much too small to possess a large independent aquarium building as in the case of New York or Chicago. Nevertheless, in planning for the new addition to the Museum of Natural History, formally opened late in 1934, a compact unit of fifteen exhibition tanks of 300 to 800 gallons each, together with storage reservoirs having a total capacity of 10,000 gallons on a gallery of its own overlooking the Hall of Marine Life, was provided for.

One of the outstanding features of this aquarium is its adaptability to the limited amount of space available in a single long room, 12 feet by 68 feet, including the long public gallery. That discouraging aspect of aquarium maintenance, the breakage of plate glass, has been entirely eliminated by casting each plate of the inch-thick, rubber-lined glass into a heavily all-welded galvanized iron frame, outside the concrete tank. This arrangement takes care of all undue tensions and strains to which ordinary aquarium glass is subject.

The inside of each concrete tank was neutralized and solvent materials removed by washing and soaking with phosphoric acid over a period of six months. Then the concrete was impregnated by blowtorch with hot paraffin, such treatment making it in many ways equivalent to an all-glass tank.

The water bill for the Springfield Aquarium is nil, for the reason that the water in the tanks is used over and over and the amount lost by evaporation and other means is replaced by pure and well-aerated rainwater drawn from the roof and stored in three large reservoir-tanks.

Replacement of water within all fifteen tanks goes on continuously, the "used" water being pumped up and passed through two filters where the larger impurities and foreign matter are removed as they pass through the gravel and bone-char medium. The water continues through the pipe lines and is distributed among the three large storage tanks where it stands with a large surface area exposed to the air, and in addition, receives much aeration from the luxuriant growth of aquatic plants within these tanks, thus adding to the oxygen content of the water and completing the factor of balance. Leaving the storage tanks, the pure and aerated water is splashed from taps at a height of six inches into the individual tanks. To meet the extra oxygen requirements of the brook trout, coming as they do from highly aerated, spring-fed brook waters, an auxiliary pipe, punctured with holes, has been set up about a foot above this tank and 30 separate jets of water steadily played on the water surface of the tank.

Care has to be exercised in the collecting of rainwater used in replenishing that water lost in circulation. It is after several hours of steady precipitation that the valve admitting the rainwater from the roof is turned on and the water allowed to pass into the two auxiliary storage reservoirs under the corridor flooring, and this only after pH and sediment tests. Most of the impurities, such as dust particles, cinders from neighboring chimneys, etc., will have been washed away, and by the steady downpour, the rainwater caught will be comparatively free of toxic and foreign matter. The smaller auxiliary tanks are

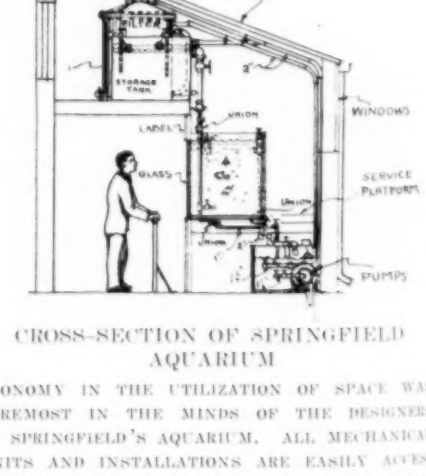
ALONG THE PUBLIC GALLERY OF THE AQUARIUM

OVERLOOKING THE HALL OF MARINE LIFE OF THE SPRINGFIELD MUSEUM IS THE ROW OF FIFTEEN EXHIBITION TANKS CONTAINING TWENTY-THREE DIFFERENT SPECIES OF NATIVE FRESH-WATER LIFE, FROM BROOK TROUT TO FROGS AND MUDPUPPIES.

connected directly with the larger reservoirs, and the rainwater is in turn mixed with the aerated water in them.

Brass pipes and fittings such as contribute to the toxicity of water are not used, but rather galvanized iron piping. In view of keeping so many different species of fish and pond life in the same water it has been found best to keep the pH at 6.8. Samples of the pH of pond and river water from which new fish come is always made and the pH of the aquarium water is brought over to duplicate as nearly as practicable the pH of the former. If it is to be raised on the alkaline side, sodium bicarbonate is the agent used, and if it is to be lowered to get an acid reaction, sodium phosphate. All new fish before being introduced to the tank containing healthy life are quarantined for a period of observation in a well-aerated and separate tank beneath the corridor floor. The chemical germicidal agent used to combat bacteria and other parasitical organisms in this tank is potassium permanganate and salt.

Very little heat has to be manufactured for the aquarium during the winter months. In the first place, the aquarium is built on a gallery three floors up, with heated air rising continuously from the first two. Steam radiators are diverted and made to heat the outside walls of the two pump tanks. Thus the water in circulation may be heated to any desirable warm temperatures by simple adjustment of a thermostat. When it is desirable to sterilize and clean the entire aquarium pumping system, the water can be completely drawn off and live steam sent through the entire length of all pipes and up through the pumps and filters. The steam-pipe lines entering the museum building from the adjacent central heating plant are laid for fifteen feet under a flower bed and the heat furnished the surrounding soil in winter enables earthworms to live and multiply out-




CROSS-SECTION OF SPRINGFIELD AQUARIUM

ECONOMY IN THE UTILIZATION OF SPACE WAS FOREMOST IN THE MINDS OF THE DESIGNERS OF SPRINGFIELD'S AQUARIUM. ALL MECHANICAL UNITS AND INSTALLATIONS ARE EASILY ACCESSIBLE AND SO LOCATED AS TO ALLOW BOTH FREE PASSAGE ALONG THE CORRIDOR AND UNOBSTRUCTED OBSERVATION FOR VISITING BIOLOGY STUDENTS FROM NEIGHBORING EDUCATIONAL INSTITUTIONS.

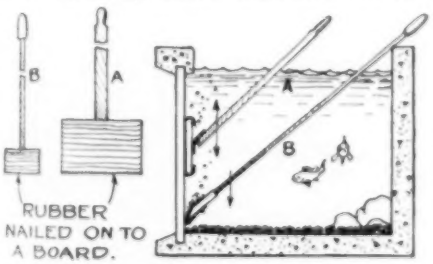
doors. The winter worm supply for smaller fish, turtles, crayfish and other forms is thus conveniently dug here at all times.

The normal water temperature in all the aquarium tanks is kept from 60° to 65° F. at all times, and that of the trout tank at 58°. Normal spawning and egg laying takes place at these temperatures.

To maintain lower water temperatures during the summer months, an old electrical commercial ice-making unit with a capacity for 900 pounds of manufactured ice every 24 hours, was installed and maintains the proper summer water temperatures.

Alga growths and bottom refuse is removed from the tanks by that efficient scavenger, the common sucker; also from the bottom by rubber suction tube; and from the glass front by a special rubber-ridged, long-handled cleaning device. The bottom of each tank is cleaned by siphoning, an hour after daily feeding to prevent the water from becoming fouled.

It has been found that in the case of the tanks with fish not having the sucking-mouth adaptation, gravel is unnecessary on the bottom and tends to make cleaning more difficult. In such cases, the gravel layer has been dispensed with, except perhaps for little banks along the front; this for the esthetic effect. The two filters are cleaned by reverse pressure or by having city water backwash through them, this being done monthly.




REMOVING ALGAE BY MECHANICAL MEANS FROM THE AQUARIUM TANKS

THE CORRUGATED RUBBER ON ITS FRAME IS ATTACHED TO LONG HANDLES WHICH ARE MANIPULATED BY HAND IN AN UP-AND-DOWN MOTION. A IS SET ON HINGES AND ALLOWS FOR MUCH FREEDOM OF MOVEMENT, WHILE B IS RIGID THROUGHOUT AND IS ESPECIALLY SUITABLE FOR GETTING AT THE CORNERS AND AREA CLOSE TO THE BOTTOM.

THE EXHIBITION TANKS OF THE MUSEUM TAKEN FROM "BEHIND THE SCENES"

THE THREE LARGE RECTANGULAR TANKS UNDER THE SKYLIGHTS DO THREE THINGS: HOLD THE FILTERED WATER; RECEIVE NEW RAINWATER; AND BY THE AQUATIC PLANTS WITHIN, AERATE IT.

The food bill for the entire community of aquarium inhabitants seldom reaches 75 cents a day. This expense item is divided between the purchase of liver, beef, pig's heart, fresh smelt and other raw meats from local fish markets. A special state fishing permit enables the museum aquarist to journey a few miles up the Connecticut River from time to time and obtain a supply of live shiners, small fish which are fed regularly to the pickerel, bass and perch. Prepared and

commercial fish foods are not used in the Springfield Aquarium because of unfortunate experiences in the past involving the introduction of disease conditions.

To achieve a well-balanced display in each tank, the aquatic life is at present being studied and rearranged. In each tank it is hoped to have a non-combative species of fish, one which is a bottom habitué. For instance, suckers and catfish are bottom denizens, while sunfish, perch and carp are what is known as "higher-ups."

In determining just what forms of aquatic life and species of fish to display in the Springfield Aquarium, both the interests and needs of the public were taken into serious consideration. It is the avowed purpose of the museum to acquaint the public first of all with local forms and to stimulate an active interest in the life habits and characteristics of such. For this reason, all local freshwater life from eels, mud-puppies, pond turtles, frogs and crayfish to tiny Johnny-Darters and large and voracious bass are on exhibition under artificial aquarium conditions which duplicate as nearly as possible actual stream conditions from which they originally came. Most every one goes fishing some time in their life in their own local waters and to see the kinds of fish one can hook; besides, labels which elaborate briefly on their life habits means much in the individual's reaching a better understanding of aquatic life and consequently away from the confusion which so often arises in the identification of fish forms in the field. Incidents like the following impress the museum staff with the usefulness and practicability of the institution's plan. The other day a devotee of the art of Walton, rigged in heavy rubber boots and complete angler's attire and carrying his fishing rod, entered the museum and aquarium gallery, made a rapid and thorough survey of the different fish and was off again. As he remarked to a member of the staff stationed on duty on the exhibition gallery, he just wanted to renew acquaintance with the tank inhabitants and get an idea of the fish he expected to encounter on his trip.

# THE MALE BIRTH SURPLUS

By DR. HEINRICH ROSENHAUPT

FORMERLY DIRECTOR OF THE MUNICIPAL HEALTH BOARD OF MAINZ, GERMANY

It is a well-known fact that of all the children born into the world alive the males exceed the females, roughly speaking, in the ratio of 106 to 100. It is often stated, and almost as often disputed, that after great catastrophes, such as wars, in which the lives of many men have been lost, the relative proportion of male births reaches a still higher figure. Statistics of the years following the great war seem to prove the truth of this assertion.

Not more than 200 years ago Johann Peter Süssmilch, theologian and statistician, wrote a book on the "Divine Dispensation in the Variations of the Human Race, proved by Births, Deaths and Reproduction." In the remarkable phenomenon of the increase of male births after periods of catastrophe he saw the hand of Divine Providence interfering to make compensation for the afflictions of mankind brought by war and pestilence. No such explanation as this can, of course, satisfy us to-day. For us the whole world order is bound to everlasting laws, and it should therefore be our endeavor to seek explanations of universal scientific validity for the variations in the male birth surplus. That is to say, we should try to ascertain what post-catastrophic conditions may lead directly or indirectly to an increase of male births, and how we are to imagine the processes of cause and effect which produce the given results.

But before we proceed to investigate this special problem, we must first recognize another remarkable fact, *viz.*, that while there is universally an excess of male over female births, at the same time the mortality among boy infants so far exceeds that among the girls that at the end of the first year of life there has hitherto generally been a surplus of girls. Moreover, there are two further points to be noted; first, among the still-births the males exceed the females by from 25 to 30 per cent., and, second, that the number of miscarriages of male offspring is almost double that of female offspring.

Christoph Bernoulli (1782–1863), not, like Süssmilch, a theologian and statistician, but a natural philosopher and statistician, already had clear views concerning the problem we are dealing with. We quote his exact words:

> . . . Moreover, we see that, in spite of the excess of male births, before the age of maturity is reached the numerical equality of the sexes is re-established through the male children being subject to a higher rate of mortality. Unmistakable as this reciprocal action and its purpose are, it becomes all the more mysterious why nature should in this way aim at a result which could be directly attained if the conditions of genesis and decease totally disregarded sex variation in the individuals. And in any case this theological purpose throws no light on organic or physiological causes which lead to a more frequent genesis of male individuals. At the most we may infer from the correlation of these two phenomena the existence also of some causal nexus.

And again,

> If in the first years of life more boys die than girls and a still more striking disproportion is found in the still-births (there are far more male embryos than females among the still-born), it can hardly be doubted that still more male than female embryos die before birth, and consequently that the sex ratio of male conceptions is considerably higher than that of male births. Unfortunately we possess no exact data at all concerning the numbers of miscarriages, to say nothing of their sex ratio. Assuming, however, that for every 16 male and every 24 female children born alive there is one case of miscarriage, we should come to the following proportions: 1,000 female births to 1,042

female conceptions, and 1,060 male births to 1,126 male conceptions, and the actual sex ratio of conceptions would be 1,082 to 1,000.

The general truth of these statements has been confirmed by later investigators in the same field. Whether the exact figures have had to be modified in the one direction or the other is of little importance for our consideration of the problem. Looking at the matter from the purely biological point of view, the fact remains that from a high surplus of male conceptions there is still a considerable surplus of males at the entrance into life at birth. With the better attention now paid to prenatal care and infant hygiene we may certainly expect in the future a rise in the number of living males. A female surplus would be quite out of the question so long as no war catastrophes caused a diminution of the male population. Those numerical relations can not be explained from any principle of racial preservation, in other words, from a teleological point of view. For racial preservation an excess of women would be of far greater importance than the reverse relationship.

We shall now try to investigate the biological causes which may account for the surplus of male conceptions and births. Düsing (*Die Faktoren welche die Sexualität entscheiden*) asserted among other things that social conditions compel many women to wait for a long time for their first conception, and that they are thus in a similar situation to that in the animal world resulting from a shortage of grown-up males. "Such mothers of advanced age at their first childbirth consequently (?) produce a large surplus of male children." Others (*e.g.*, Goehlert, *Morel de Viade*) have shown that, in the case of horses and sheep, with the advancing age of the female parent there is a corresponding increase in the surplus of male offspring. A similar result is said to have been observed in the case of American cattle when the parent bulls have become exhausted by excessive service. On the other hand, in herds containing a large number of bulls, which are consequently less overworked, there is said to be a majority of cow calves (Fiquet). Similarly, it is asserted that the female offspring of domestic animals increases in number in proportion to the richness of feeding of the parents. Martegoute has found that the mothers of ewe lambs show on an average a heavier weight than those which give birth to male lambs. Landois, experimenting with many thousands of larvae of the vanessa urticae (small tortoise-shell butterfly) succeeded in breeding males or females at will, according as he fed them well or not. The influence of food on the sex ratio has been expressed in the language of political economy by Ploss in the following concise form: "The male surplus rises with the prices of food."

From the foregoing statements it appears that under certain conditions inferior nourishment may influence the sex ratio in favor of the male sex and that sexual exhaustion may have a similar effect. Possibly this latter assumption may account for the special preponderance of males in the offspring of first births of which we shall have to speak later on. Zappert asserts that very young or very old mothers and also illegitimate mothers bear more boys than correspond to the ratio 106 to 100. We have, therefore, apparently to assume three kinds of "weakening" influences: (1) sexual exhaustion, (2) exhaustion through age, and (3) underfeeding.

Famine-stricken Germany in the year 1918, with its ratio of 108.5 to 100, confirms the truth of the last-named factor. Chronic poisoning may apparently also be booked as a weakening factor, for Bondi quotes animal experiments which show that male parents that have been subjected to alcoholic intoxication and mated with young females bearing for the first time produce mostly male off-

spring of inferior weight. Lenz sets up the hypothesis that the male-determining spermatozoa which contain fewer chromosomes come more easily to fertilization when the sperm cell is injured or the egg cell impaired than the female-determining spermatozoa which are well laden with chromosomes. A French investigator, R. Worms (*La sexualité dans les naissances françaises*, Paris, 1912) has ascribed the surplus of male births as well as the (previously mentioned) higher mortality of male children to unfavorable life conditions of the parents, and, in proof of this, he says that with the general increase of welfare in the nineteenth century the male sex ratio of live-born children sank from 107 to 104, and that of still-births from 150 to 135. In contrast to this, Lenz, on the other hand, in the Handbuch of Rubner, Gruber and Ficker, asserts that in Germany the surplus of boy deaths was lower in the war years 1916 and 1917 than it had been previously. The social hygienist can easily find an explanation for this contradiction. The increased attention given to infant welfare, which had formerly been much neglected but was now vigorously carried on in the years of war and distress, had acted especially to the advantage of the more susceptible boy children, independently of the nutriment conditions of the parents. Moreover, the scarcity of milk compelled the mothers to nurse the children themselves, which meant their rescue from an early death through faulty feeding. During the siege of Paris in 1870–71 the failure in food supply had a similar effect to the benefit of the infant.

An unpublished doctor dissertation by Grünewald, *Die Übersterblichkeit der Knaben im Lichte der Erblichkeitslehre* (The excess mortality among boy children in the light of the laws of heredity), 1923, says, "The determination of sex depends on mendelising hereditary factors in which the female sex is homogamous and the male heterogamous. Consequently some of the recessive morbid heredity factors are as a rule effective only in the male sex, *e.g.*, red and green color-blindness, haemophilia, hereditary atrophy of the optic nerve. These sex-linked recessive hereditary dispositions produce their effect in uterine life and early infancy."

In proof of the correctness of this view concerning endogenous causes and of our remarks on the value of infant hygiene, especially in respect to boy children, we may quote the fact that in the year 1911, as a result of special protective measures taken against the external dangers of the abnormally hot summer of that year, the boy death ratio was successfully reduced below the average of the ten years from 1906 to 1916, *viz.*, from 119.2 to 116.9. Grünewald's further contention that endogenous factors outweigh the exogenous in importance—in support of this he gives a curve according to which the excess mortality of boys is in inverse proportion to the total infant mortality—can only be considered correct if he includes, not only hereditary, but also pre-natal influences among the endogenous factors. But as these latter are also influenced by external factors (food conditions, illness, work), it seems to us that they can hardly be classed among the endogenous factors.

This disagreement concerning definitions or nomenclature is no mere "querelle allemande," but is of importance in connection with the problems of maternal welfare. It is easy to declare ourselves powerless against endogenous factors, whereas we do possess means for directing or modifying exogenous factors. The factors that lead to a post-catastrophic increase in the number of boy births should also be capable of determination by comparing the statistical figures supplied by the nations at war with those supplied by neutral nations. In one of the publications of

the medical section of the Board of Health of the Reich (*Statistische Kurzberichte* XV, *Deutsche Medizinische Wochenschrift*, February 19, 1937) an attempt to do this has been made. Three different periods are compared in Table 1. Only slight variations are apparent.

TABLE 1

| Periods | Boy birth surplus | |
|---|---|---|
| | In nations at war | In neutral nations |
| 1915–18 ..... | 105.9 | 106.2 |
| 1919–20 ..... | 107.6 | 106.7 |
| 1921–23 ..... | 105.8 | 106.2 |

One proposed explanation made in the publication mentioned seems to us to be of some considerable importance, though it gives no positive answer to the question at issue, but involves a shift in the formulation of the problem. First births are said to show a relatively larger number of boy births than subsequent births, so that the mass marriages following the end of a war may be a sufficient explanation of the increase in the number of boy births.

Statistics from the United States of America for the two periods 1922–24 and 1927–29 are adduced in proof (Table 2).

TABLE 2

| Total number | | Ratio of male | |
|---|---|---|---|
| | | live births | still-births |
| First births .... | 135,943 | 106.11 | 135.16 |
| Second " .... | 67,452 | 106.0 | 135.0 |
| Third " .... | 46,589 | 105.81 | 135.14 |
| Fourth " and later .... | 153,365 | 105.23 | 136.50 |

Similarly in Germany in the year 1934, in which the number of first births was specially high, a maximum figure of 106.9 was reached in the male birth ratio for the period from 1922 to 1934. The explanation for this is to be found in the state propaganda for an active population policy by means of government grants of marriage loans.

It must not, however, be overlooked that the above-mentioned theories, according to which male births are to be expected from a "weakened" father, are rejected by some authorities and that Vaerting, for instance, asserts that "every misuse, every overexertion of physical or mental powers on the part of the father" leads to boy death. Further, it is said that in harems, in consequence of the sexual exhaustion of the father, for every hundred girls born there are only 25 boy births! (In regard to this last statement one can hardly suppress the suspicion that an "active" depopulation policy has here cooperated in some way or other with the practice of polygamy.)

Equally contradictory are the statements made concerning the influence of so-called race mixture on the number of boy births. (There seems to us to be no justification for considering this as a purely biological problem. Alone the fact that racial crossings in colonial countries are often associated with very great changes in the social and economic circumstances of the mating parties makes it hardly possible to form any exact appraisement of the biological factor). Against statements from Argentina that pure Italians show a boy surplus ratio of only 100.77, pure Argentinians (surely a racial mixture scarcely capable of exact definition) a ratio of 103.26, and mixtures of the two 105.72, we have Eugen Fischer's statements, who calculates a ratio of 108.1 for pure Boers and 107.6 for Rehoboth bastards (Boers with Hottentots).

An altogether special problem seems to be present by relations among the Jews. Among the orthodox Russian Jews the quota for boy births is said to be very high. For this the explanation is given that religious injunctions forbid sexual intercourse during the first 12 days after menstruation and that in a subsequent conception the ovum involved is overripe and consequently predisposed to produce a male offspring. (Whether

this theory can be maintained in the face of the recent spectrographic methods of Samuels (Amsterdam), proving the possibility of repeated ovulations within a single menstrual period, must be an open question). According to the views of present-day German racial speculators the Jews do not form any real race, but a peculiar kind of racial mixture, so that racial-biological conclusions are altogether to be regarded with suspicion. The hygienist Hueppe says concerning this point that with the Jews religious tradition has taken the place of purely racial heredity and has converted a racial mixture into a national unit in which religious injunctions have developed into the code of social hygiene of a "vital race."

A certain contrast to this is presented by the views found in a publication of over eighty years ago. A Hungarian medical officer, Glatter, in a lecture which contains much else that is interesting also from other points of view, compared the Jewish and the Christian population of a small, but to him well-known, district. He expressly stresses the point that there were no essential differences in the economic circumstances of the two groups. The Jewish population under consideration, which was subject to no migratory influences, numbered 1,952 in the year 1833 and 2,462 in 1856. In the intervening 23 years between these two dates no illegitimate child was born. Wedlock fertility amounted to 3.77 per marriage, compared with 3.93 in the rest of the population. The ratio of boy births was 116 to 100 girl births, while for the rest of the population the ratio was estimated at 105 to 100. Glatter further finds that among the Jews infant mortality was lower and the length of life higher than in other sections of the population. He thinks that these peculiar relationships can only be understood by assuming a racial difference. In regard to the sex ratio, in which we are here specially interested, we must regret with the author of the investigation that he had no statistics at his disposal concerning Jewish still-births in the period investigated by him. But he expressly mentions that contemporary statistics for Prussia show that the ratio of still-births to the total number of births was 1:20 or 1:25, but only 1:40.5 in the Jewish population. He also points out that the Jewish expectant mother takes better care of herself than the Christian mother in the same circumstances. If we assume that prenatal care must act above all in favor of the more numerous, but at the same time more delicate, male embryos—the smaller number of still-births seems to confirm this—there is no need to assume any racial, *i.e.*, biological, difference to account for the sex ratio, but we can find an explanation in the precautions taken against harmful environmental influences.

Dr. Göllner, in the "Reichsgesundheitsblatt" for 1935, p. 980, has also investigated the question of the supposed influence of the Jewish "race" on the sex ratio, particularly in the case of mixed marriages between Jews and Christians, marriages between partners of different racial extraction but of the same religious confession being naturally left out of account in accordance with the records of the marriage registers on which his investigation was based. These have hitherto only noted the religion and not the race of the individuals concerned. In the first place, it is not without interest to note that during the world war such mixed marriages in Germany outnumbered the marriages between two Jewish partners. In 1915 there were 104 mixed marriages to every 100 purely Jewish marriages; in Berlin the ratio was even as high as 115 to 100. The fertility of mixed marriages amounted to 0.8 live births as compared with 2.7 children born alive from pure Jewish marriages. The ratio of boy births was far higher than the

average of about 106, *viz.*, 115 on the whole, 109 with Jewish mothers and even 119 with Jewish fathers. The author raises the question whether a "bastardizing factor" is here at work. The low degree of productivity in these mixed marriages would seem to suggest that among the births the number of first-born was especially large. It has already been mentioned that among the latter the boys were altogether above the average, though the ultimate causes for this phenomenon has not been discussed. These may be of biological, but also of sociological origin. The assumption of the latter seems to be justified when we consider the economic circumstances of the Jewish-Christian partners. Whether the difference in the two categories, Jewish father or Jewish mother, has any connection with the lower fertility of one category or with different social combinations, it is difficult to say.

Max Marcuse considers that mixed marriages in which the father is Jewish are often the outcome of previous so-called "Verhältnisse" (irregular sexual partnerships without marriage), and the assumption suggests itself that after a long prenuptial period in which contraception has been practised there is consequently no great desire for offspring in the succeeding period of wedlock. Mixed marriages in which the mother is Jewish, on the other hand, are not seldom money matches, in which these influences may be assumed to have less decisive weight. (Moreover, in marriages of longer duration there are probably many cases in which one co-partner has adopted the religious confession of the other and subsequently born children are consequently not registered as the offspring of a mixed marriage, and the boy birth surplus wrongly appears so high). In both the forenamed cases the low degree of fertility registered naturally makes the proportion of first births and consequently of boy births appear larger; among the children of Jewish fathers in marriages of probably still lower fertility the quota of boys must accordingly be especially large. The assumption of "inadequate mixture of germs" seems to be altogether beside the mark, since sociological reasons can be found for the peculiarities of these so-called mixed marriages. The attitude which leads to a limitation of conception is to be found chiefly in the well-to-do sections of society—and it is from them that probably most of the mixed marriages are recruited—but at the same time it is in these sections above all that the desire and the means to spare the mother in the period of pregnancy and to give her all necessary care before, at and after childbirth are to be found. It is therefore not likely that "bastardizing factors" are responsible for a higher ratio of boy births, but rather the effects of the limitation of births and the avoidance of stillbirths through better maternal welfare. Statistics from America, which we owe to the kindness of the statistician Dr. Louis J. Dublin of New York and which are based on the records of the Bureau of the Census, Department of Commerce, for 1933, give no support for the assumption of a bastardizing factor as tending to raise the ratio of boy births and its effects in favor of a higher proportion of boy births.

To sum up, we come accordingly to the following conclusions:

(1) The post-catastrophic increase in the ratio of boy births seems to be an established fact.

(2) The main cause for this increase must be seen in the preponderance of first births, which in their turn are the result of the accumulation of marriages.

(3) The assumption of racial influences as an explanation for an increase in the number of male births must be rejected; economic and social factors seem rather to be responsible.

(4) On the other hand, it seems to be beyond doubt that maternal welfare be-

fore and at childbirth acts most strongly in favor of the more numerous but relatively less resistant male offspring and therefore must tend to raise the boy birth ratio.

(5) In addition to the measures of maternal welfare, provisions made for better infant welfare likewise tend to increase the number of surviving male infants, so that, in consequence of all improvements in mother and infant welfare together, instead of the former surplus of females a male surplus results. This fact is proved by the latest figures given in the 1937 volume of *Wirtschaft und Statistik*. In 1936 the ratio between the boys and girls alive in Germany was as follows:

Below 6 years, 965 girls to 1,000 boys.

From 6 to 15 years, 969 girls to 1,000 boys.

From 15 to 20 years, 977 girls to 1,000 boys.

There is thus already an increase in the living boys surplus visible within the last 20 years.

# MIND IS MINDING

By Professor LESLIE A. WHITE

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We should have a great many fewer disputes in the world if words were taken for what they are, signs of our ideas only, and not for things in themselves.—LOCKE, "Essay on the Human Understanding."

"THE problem of the relation between body and mind has occupied philosophers and scientists since the dawn of thought, and to many it appears no nearer a solution now than then. It has been named the central problem of all philosophy, fundamental alike in the theory of knowledge, in ethics and in religion. Not less fundamental, however, is it for psychology and for physical science. . . ."

These are the opening words of the article "Body and Mind" in "Encyclopedia of Religion and Ethics,"[1] by James Lewis McIntyre, Anderson lecturer in comparative psychology to the University of Aberdeen. Hundreds of books and thousands of lectures and articles have been devoted to the "mind-body" problem. How is it possible for the body to have a mind? How can the mind have a body? Which is the reality, the body or the mind? How are body and mind articulated with each other? These are some of the questions which have plagued us for many a century. And "to many they appear no nearer to solution now than then."

Why has the "solution" not been reached? Where is the difficulty?

It is the thesis of this essay that the "solution" has not been reached because the problem is a false one, somewhat like the paradoxes of Zeno. The difficulty is one of verbal origin; it is of our own making. By rewording the problem the "problem" disappears: use the word mind as a verb instead of a noun and no "problem, fundamental either to the theory of knowledge, ethics, psychology, science" or to anything else, remains. Mind is minding; it is the behaving, reacting, of a living organism as a whole, as a unit.

Once upon a time, in a far-off land, a people was concerned with the problem of Golshok. No one knew *exactly* what Golshok was, but every one agreed that he (she or it) was very important and that their existence and welfare depended in large measure upon Golshok. Many of the best minds of this people devoted

[1] Edited by James Hastings, 1909.

their lives to the study of Golshok. Their lucubrations were recorded and their pronouncements carried great weight. It was decreed that all social life was to be conducted in accordance with the principles of Golshok as set forth by the wise men. Of course it was necessary to put people to death occasionally because of their failure to comply with these principles. This was usually done by burning them alive. This went on for centuries. But not all people were content. Some were bent upon discovering just what Golshok really was—if anything. But they never got any farther than words, save for an occasional burning of a rebel.

Finally some one broke a way out of the impasse. He declared in plain language that the whole Golshok business, from start to finish, was nothing but "words, words, words," that the wise men had been chasing their tails for centuries, with "the solution no nearer now than then." He declared, moreover, that if people would conduct their lives upon human principles instead of Golshok principles they would be much better off.

Of course the wise men had him burned to death and his ashes scattered to the four winds. But they were too late. The secret was out. The common people went around saying, "There ain't no Golshok." And they lived happily ever after.

And so it has been with "Mind." "Mind" is a noun. A noun is a name of something. Therefore there must be something in the cosmos that *is* mind. A person has a mind; it is possible for him to "lose" it. Thus "mind," an entity, a "thing-in-itself," was created and projected into the cosmos. Then people set about trying to find it as they have been searching for truth, the good and beauty, these many weary years. One might as well search the cosmos for $\sqrt{-1}$. Philosophic tail chasing, nothing more.

Organic phenomena are distinguishable from inorganic phenomena: the former have a cellular structure, they appropriate items in their environment and assimilate them into their own cellular structure. Organic bodies move, react, behave. We may distinguish two categories of reactions of living beings—(1) the reactions of parts of the organism with reference to other parts, and (2) the reaction of the organism as a whole, as a coherent unit, to its environment. The reactions of the first category constitute the field of the physiologist; those of the second category the province of the psychologist. The reacting, behavior, of any living organism as a whole, as a coherent unit, with reference to its environment, is minding, or mind.

This commits us to such statements as "An oyster has a mind." Similarly, a paramecium, a radish, a lichen, have "minds." It may sound ridiculous to say that a radish has a mind. But it sounds much less ridiculous to say that a radish *minds, i.e.*, reacts to its environment, behaves, does something as a unit. So much are we at the mercy of words that even so slight a change as one from noun-use to verb-use makes the whole world look different. All living creatures possess the property of reacting to external stimuli as coherent, organic units. Mind is coextensive with life.

We come now to kinds of minding, kinds of reacting or types of mind. Obviously organisms behave differently as their structures differ. The mind of man is not the same as the mind of ape or starfish or radish. There are patterns or types of minding or mind, just as there are patterns or types of structure. This does not mean, however, that a classification of patterns of reacting would correspond, point for point, with a classification of structures; classifications may vary legitimately with point of view and purpose. The classification of types of

reaction, of mind, has not been well worked out as yet.[2]

To return to our starting point: what is mind? How can a mind have a body? The solution: mind is minding, the reacting of an organism as a whole, as a coherent unit (as distinguished from the reacting of parts of the organism with reference to other parts). Mind is a function of the body. The "organ" of the mind is the entire organism functioning as a unit. Mind is to body as cutting is to a knife.

But Alexander merely *cut* the Gordian knot; he did not untie it. Neither have we "solved" the mind-body problem, for in the form in which it has plagued the reflecting portion of mankind, it is insoluble. But we have disposed of it. We have not proved, nor can it be proved, that there is no cosmic entity, mind, which has an existence independent of bodies. We have not proved that the "fundamental reality" is not mind, of which bodies are but material expressions. So far as the present writer knows, there is no convincing proof for the non-existence of Santa Claus. Mankind progresses, often, not by disproving propositions but by outgrowing them.

The "Mind-Body" problem is of one piece with the Vitalism-Mechanism controversy. No one has ever "disproved" the theory of Vitalism, but scientists, and many philosophers, are agreed that the time has come when it should be ignored as obsolete, outgrown and, above all, sterile. It is not that the philosophy of Mechanism is True (with a capital T) and that of Vitalism False. It is that Mechanism has been fruitful, productive; Vitalism barren and sterile. Vitalism as "a view is exactly opposite to those which *have led to all the scientific progress that has been made,*" declares Professor H. H. Newman.[3] Biologists have "clung to the materialistic or mechanistic explanation of life, simply because *it was the only way in which progress could be made*" (emphases ours), declares the distinguished paleobiologist, Professor Ermine C. Case.[4] The philosopher Bertrand Russell declares: "To invoke a vital principle is to give an excuse for laziness . . . the opposite view [mechanism] is, scientifically, a more fruitful working hypothesis."[5]

And so, while we have not proved that mind is not some cosmic entity, or proved that it is not the "real reality," we have shown that this view is barren and sterile at its best and confusing and paralyzing at its worst. The opposite view, that mind is minding, or behavior, that mind is a function of the body, releases us from the verbal bondage of a sterile and a paralyzing metaphysics, and sets us free to sow and reap in a field that will bear fruit.

[2] In "The Mentality of Primates" (SCIENTIFIC MONTHLY, Vol. 34, January, 1932) the present writer set forth a brief and preliminary sketch of types of mind. He has since refined and amplified this earlier statement, and plans to publish his results soon.

[3] In an essay, "The Nature and Origin of Life," in "The Nature of the World and Man" (H. H. Newman, ed.), p. 164, Chicago, 1926.

[4] In *The Michigan Alumnus*, p. 3, March, 1934.

[5] "Philosophy," p. 25, New York, 1927.

# COMMENTS ON CURRENT SCIENCE

## MODERN REFRIGERATION

REMEMBER the ice man? In the pre-war variety he is nearly extinct, but refrigeration is a booming industry these days because of the expanding use of cold-making in food and beverage preservation, air-conditioning and industry. Refrigeration has become one of our complex mechanical industries.

A refrigerating engineer may be called upon to provide anything from ice cubes for a cocktail party to a snowstorm for a movie production. While the electrical or gas household refrigerator, making in your own home its own low temperature, has largely outmoded the ice box, the major task of refrigerating experts may include not ice and low temperature production, but anything that helps preserve foodstuffs or manufacture weather.

At the recent meeting of the American Society of Refrigerating Engineers in New York, American pear growers were advised to adopt the British method of adjusting the atmosphere in cold storage warehouses that allows Bartlett pears to be kept some six months instead of a few weeks. Confirming research at Cornell University shows that the trick is to adjust the carbon dioxide given off by the fruit itself to just the right amount.

Ultra-violet lights are finding their way into cold storage plants and packing houses to kill molds and bacteria that otherwise, even with refrigeration, might spoil the food being stored.

Mass attacks upon bacteria must be used to be effective because it requires 1,250,000,000 average size bacteria to cover an area of one square inch.

One of the most modern methods of food preservation is quick freezing. Extreme chill catches the food before it can change and keeps it fresh for months.

In the research laboratory low temperatures are useful in testing the way automobiles, materials, oils, engines and other useful things react under severe frigid conditions.

The refrigeration industry has come a long way from the days when our grandfathers cut pond ice in winter and stored it in sawdust against the summer's heat.

WATSON DAVIS

SCIENCE SERVICE

## PROBLEMS CREATED BY AIR-CONDITIONING

WITH air-conditioning coming into wide-spread use in larger, public buildings, the heating and ventilating engineers who have made this advance in human comfort possible are now faced with some serious problems which they have thus created.

As one example, what health risks are there involved in the recirculation of cool air through a crowded motion picture theater, restaurant or office building? It is hardly economical to use the cooled air only once and take in completely fresh air at each cycle in the air flow. Thus only a fractional part of fresh air is taken in.

Since this situation exists, the question arises whether the bacteria content of the air in an air-conditioned building gradually rises. If it does, does it approach a bacteria concentration which is potentially menacing to health?

In hospitals, too, there is the problem of what to do about the ventilation of contagious disease wards whose air passes into a common system and, potentially, may be recirculated through the whole air-conditioned hospital.

More widely known among laymen is the problem of ridding restaurants and railroad cars of the odor of smoke. Here the problem is complex because it not only involves the cleaning of the air and

its recirculation but the removal of elusive odors.

The research committee of the American Society of Heating and Ventilating Engineers is considering these and other problems. They are formulating experimental projects which will seek the best solution. The task, they well realize, will be slow, for the problems involve medicine, biology, chemistry and physics, as well as engineering.

ROBERT D. POTTER

SCIENCE SERVICE

## SCIENTIFIC RESEARCH AND WAR

POTENTIAL war absorbs too much of the world's inquiring brain power to please those who desire more expenditures for making the world a better place in which to live. A recent estimate is that of all the money spent in research in the United States and Great Britain, one fourth goes for military research. The percentage must be even larger in a nation like Germany.

Half of the research money is credited to industrial research and related pure research in physics and chemistry. Even some of this is a military expenditure in the last analysis. Most of the remaining fourth is devoted to agriculture and its supporting sciences. Social and humanistic sciences receive "such an infinitesimal part of the total as to be scarcely discernible!"

In Great Britain, where an articulate group of scientists deplore and expose the "frustration of science," government estimates for 1938–39 show the ratio of 5 to 1 in favor of research funds for military purposes. Admiralty and air ministry research grants total $22,900,000 compared with $4,500,000 for the Department of Industrial and Scientific Research and the Medical Research Council. And some of the industrial and scientific research expenditures are as much for military as for industrial purposes, such as those for aircraft design.

With photographs of destroyed Spanish universities to drive home the point, the science frustration exhibit comments that scientific research to improve warfare is a strange and indirect sort of suicide for the scientist.

In military research the internationalism of the scientist disappears and this contributes markedly to inefficiency. Not only is there no free interchange of information across national borders, but a British commentator says "it is found necessary to segregate the worker from the rest of his scientific colleagues by forbidding mention of his work outside his laboratory."

WATSON DAVIS

SCIENCE SERVICE

## DESTRUCTION OF SYNTHETIC CLOTH BY BACTERIA

THE making of synthetic wool-like fibers from the casein of milk is a truly amazing development of modern chemistry. When such fibers are blended with natural wool, beautiful and serviceable fabrics are obtained.

But milk is quickly acted upon by bacteria, and scientists have been wondering if the synthetic fibers too might be susceptible to attack by micro-organisms.

Two Dutch scientists have investigated these "wool-from-milk" fibers and have found that bacteria, which ordinarily are able to destroy proteins of the casein class, succeed in completely dissolving the synthetic fibers. In a fabric made entirely of the synthetic fibers the destruction was complete. In a mixture of 50 per cent. synthetic wool and 50 per cent. genuine wool only the synthetic wool was destroyed.

Jan Smit, lecturer in microbiology at the University of Amsterdam, and his colleague, B. van der Heide, of Wageningen, report to the British science journal *Nature* on their experiments proving these findings.

"It was found," they state, "that nearly all casein-splitting micro-organisms, isolated from soil or manure or gathered by infection from ordinary atmosphere, are able to attack the (synthetic) wool."

The action of the organisms appears to be by means of an enzyme, *i.e.*, by liberating a chemical that attacks the synthetic wool.

Heating the fibers and bacteria to the temperature of boiling water appears to destroy the enzyme reaction so that one might speculate whether wearers of such synthetic wool clothing would have to boil their suits periodically.

However, the destruction is more academic than practical, for it can be recalled that most of the world's buttons are now made of casein and no one worries greatly about bacteria destroying them in actual use.

ROBERT D. POTTER

SCIENCE SERVICE

## INSULIN SUBSTITUTES

SOVEREIGN remedy for the treatment of diabetes is insulin, the chemical produced by a group of cells in the pancreas called the islands of Langerhans.

The dramatic story of the discovery of insulin and of the consequent rescue of thousands of patients from both death and a miserable starved existence that made death a welcome release has been told and retold.

Yet stories of insulin substitutes, which can be swallowed instead of injected hypodermically, keep cropping up and arousing hope that all diabetics can keep well without the bother of needle and syringe.

In view of these stories, and to emphasize the fact that so far insulin substitutes to be taken by mouth are only in the hoped-for stage, it might be well to summarize a discussion of the subject by Dr. Hans Jensen, of the Johns Hopkins University, in his recently published book, "Insulin."

Dr. Jensen says that at present there is no substance which is non-poisonous and which can be given by mouth as a substitute for insulin in the treatment of diabetes. A number of substances, he points out, have been found which reduce the amount of sugar in the blood and which when given to patients with mild diabetes have caused a decrease in the sugar in the urine. Yet there are objections to each of them which have prevented their being universally accepted for treatment of diabetes.

The crucial test which an insulin substitute must pass, before being used for treating patients, Dr. Jensen says, is its ability to prevent symptoms of diabetes in animals from which the entire pancreas has been removed. Insulin itself does this.

These remarks on insulin substitutes do not refer to the new, so-called "slow action" insulins, which are prepared from insulin itself but altered so as to prolong the effect of the insulin.

JANE STAFFORD

SCIENCE SERVICE

## PROBLEM-SOLVING ABILITIES OF DOGS

DOGS display marked individual differences in "I.Q.," no less than their two-legged lords and masters, Dr. E. G. Sarris, of the Institute for Environmental Research in Hamburg, Germany, has found. Tested by their abilities to solve problems connected with the getting of a coveted piece of meat, their mental abilities ranged all the way from very bright to plain, doggone dumb.

Dr. Sarris started with eight dogs of assorted sexes, breeds and ages. At first he gave them an easy problem, of getting the meat when they were separated from it by a serpentine fence constituting a simple maze. All the dogs could solve that one, though some of them made

hard work of it, while the cleverer individuals went through it very quickly.

Then he increased the difficulties, imposing such brain-puzzlers as getting the meat out from under a can loaded on top with bricks, hauling it over a wall on the end of a string, moving small carts and boxes that would enable them to reach it when it was hung too high for direct approach, etc.

At each set-up in difficulty, some of the animals found the problem too hard and gave it up. Finally, Dr. Sarris was working with his two brightest dogs, a male named Argos and a female named Niki. They could think their way through all the problems he posed them. Of course, Dr. Sarris was careful to devise situations in terms of dog mentality, rather than of human minds.

The Hamburg zoologist believes that practical uses of some importance can be derived from his study. His results, he holds, cast considerable doubt on the universally accepted idea that certain breeds of dog are best for particular working purposes, like herding or hunting. Of far greater importance, he believes, is a dog-by-dog examination for individual differences in learning capacity, based on individual variations in temperament and intelligence.

FRANK THONE

SCIENCE SERVICE

## SOUTH AFRICAN FOSSIL MAN-APES

IN 1925 Dr. Raymond A. Dart, of Johannesburg, South Africa, found in a late Cenozoic limestone near Kimberley an incomplete fossil skull of an immature creature which Dr. Hrdlička stated was doubtless *a* missing link, one of the many now extinct forms which bridge the gaps between the present widely diverse families of apes and man. In 1936 a fossil skull and upper teeth of a somewhat similar anthropoid ape were discovered in a limestone quarry near Johannesburg. Professor William K. Gregory and Dr. Milo Hellman, of Columbia University, reported at the meeting of the American Association in Richmond on the conclusions they have drawn from their recent examinations of the teeth of this interesting pre-man, technically known as *Plesianthropus transvaalensis*.

The skull presents such an astonishing mixture of ape and human characters that Drs. Gregory and Hellman were in doubt whether the fossil is that of a very progressive ape or of a very primitive man. The teeth, however, added greatly to their knowledge of the relationship of *Plesianthropus* to other primates. Modern apes use their sharp canine teeth to pierce and tear such things as tough fruits, bamboo shoots and sugar cane, and they cut them into small bits with their characteristic molars. Primitive men, on the other hand, use incisor-like canines to bite into and hold to such softer materials as flesh, and nearly flat-topped molars to grind up flesh, small bones and grains. The teeth of the South African man-apes were intermediate in structure. The gorilla lives almost exclusively on fruits; the abundance of broken baboon skulls in the caves of the man-apes suggests that the latter were eating the brains of the former, perhaps in the first stages in the acquisition of partly carnivorous habits.

Anthropologists have long been puzzled at the many curious anatomical agreements between men and orangs, in spite of their radical differences in locomotion. These investigations suggest that man and the orang may have diverged rapidly and greatly from a more chimpanzee-like ancestor, and that the South African man-apes are late survivors of this early stock. If this conclusion is correct, they are truly related to all the chimpanzee, gorilla, orang and human branches which developed as a result of rapid morphological changes that took place during

periods of vulcanism and glaciation a few million years ago.

F. R. M.

## TWO CIVILIZATIONS IN OLD STONE AGE EUROPE

EVEN in the Old Stone Age, Europe was far from simple. This surprising thought is advanced by Professor M. C. Burkitt, Cambridge University archeologist.

Europe, he declares, was nearly as complex in the Old Stone Age as it is to-day. And he is referring to the early part of the Old Stone Age, when we are apt to think of all human beings as dressing alike in skins, sleeping in caves, and spending the days in the same routine of hunting, fishing, eating and pounding out stone gadgets, all more or less similar to the unpracticed eye.

But, as Professor Burkitt surveys the prehistoric scene, he finds that two distinct civilizations can be distinguished, occupying each its own stretches of land in Europe, and also Asia and Africa. The trail of their stone tools, which each civilization made differently, enables Dr. Burkitt to show how the two Stone Age camps stood apart. He believes that they must have been foreign to one another in other ways, but their stone work is the main evidence of their civilization left.

One of these earliest civilizations made tools by chipping flakes off a piece of stone until the core was a serviceable shape. The other civilization adhered to the idea of striking a flake off a stone core, and then finishing the flake itself as a tool.

Within these two divided camps, groups of Stone Age people were further differentiated by customs and patterns of living. These differences may have been influenced by the climate and geographic features of the country they lived in.

So, however much we may like to reduce the Old Stone Age to a simple pattern, Dr. Burkitt says that the facts have opposite indication. Humanity in the past, like humanity in the present, he declares, was complex.

EMILY C. DAVIS

SCIENCE SERVICE

## WHAT IS AN ENGINEER?

To most people an engineer is the man who runs a railroad engine. And a civil engineer is an engineer who politely tips his hat to a lady!

Of a different sort are professional engineers who might be called applied scientists. They are of various varieties, from the civils who build dams, bridges, buildings, roads and other structures, to the chemical kind who engineer the production of new kinds of substances out of raw materials.

The engineer differs from a scientist in that instead of creating new knowledge he applies known technology to the tasks that need to be done in our busy world. The engineer also mixes with his technology a bit of management, finance and organization. In fact, most engineers consider themselves within the ranks of neither capital nor labor, but units in an intermediate managerial class.

Just as engine operators are called engineers, some persons who perform merely technologic functions are also called engineers. The professional engineers feel that there should be a category of technologists for those unconcerned with economic aspects.

This question of names and definitions provides perennial discussion. Latest description of an engineer is by President Karl T. Compton, of the Massachusetts Institute of Technology, in collaboration with a committee of the Engineers' Council for Professional Development:

"An engineer is one who, through application of his knowledge of mathematics, the physical and biological sciences and economics, and with aid, further, from results obtained through observation, experiences, scientific discovery and invention, so utilizes the mate-

rials and directs the forces of nature that they are made to operate to the benefit of society. An engineer differs from the technologist in that he must concern himself with the organizational, economic and managerial aspects as well as the technical aspects of his work."

SCIENCE SERVICE WATSON DAVIS

## NUMBERING AUTOMOBILE LICENSE PLATES

IT is evident that automobile license plates should be so numbered or otherwise marked that they can be most quickly identified and best remembered. With more than a million cars registered in several states, the number of numerals or letters necessary to give each one of them a distinguishing license plate becomes six, and most states require at least five.

The problem at once arises whether license plates containing only numerals or only letters or both numerals and letters are most satisfactory. The variety of license plates now in use indicates that opinions differ greatly. Fortunately the problem of determining the best type of numbering has been investigated by Professor Adelbert Ford and Mr. George F. Derr, of Lehigh University. They tested particularly the readiness and certainty with which preassigned five-symbol license-plate combinations of numbers, numbers and letters or letters alone could be identified among a series of similar license-plate combinations.

It was found that license plates consisting of one letter and four numerals are most easily recognized. Any combination of letters and numerals is superior to numerals alone, and plates consisting only of numerals are superior to those consisting only of letters.

F. R. M.

## THE CARE AND PRESERVATION OF DOCUMENTS IN RUSSIA

REPAIRING frail and important documents is proving of importance in Russia.

Some one brings in a wad of mouldy papers or a mass of papyrus and says hopefully, "Can you fix it?" and often enough the expert does, by aid of chemicals, lights or electricity.

The Soviet Union has a laboratory for preserving documents, which is doing ingenious work, judging by a report from the Soviet telegraph agency, Tass.

Explorer Peter Kozlov brought from Khara Khoto in Mongolia a great library of 2,000 Chinese scrolls. So mouldy and matted were the thin sheets of Chinese paper that they looked like sticks. To dry them, the laboratory scientists used a special table charged with static electricity of high potential. Gradually, the fragile paper opened.

A bundle of birchbark inscriptions from the Volga German republic was so crumbly that it had to be fixed into thin plates of plastic. Then, by aid of infrared light, the text was revealed. Eighteen sheets of it are in language of the Uigur tribe, dating from the thirteenth century when the Golden Horde overran Europe. These sheets are believed to be the only writing in this language known.

Even tree trunks and branches, inscribed in the little-known Sogdian language, were brought to the laboratory, for first-aid in their preservation.

The future, as well as the past, is the concern of any document laboratory. The Soviet establishment is attacking the problems of space-saving and permanence of records by adopting micro-documents, tiny in size. Instead of microfilm, the most usual form, it plans to use thin layers of platinum containing 20 pages of text, enclosed between layers of special glass. Boxes of smelted diorite or basalt will be made to hold these records. The constitution of the Soviet Union in the numerous languages of its people will be the first document thus prepared.

EMILY C. DAVIS

SCIENCE SERVICE

# BOOKS ON SCIENCE FOR LAYMEN

## INVENTION AND THE AMERICAN SOCIAL PATTERN[1]

In order that a book may claim the attention of the alert reader it must have an interesting subject-matter, an engaging style and a point of view. The "March of the Iron Men" has these excellent qualities and more. Not before has there appeared so remarkable an assembly of the significant facts about invention together with a recitation of the individual items invented, all linked to a social philosophy that is thought-provoking in itself and that moreover is vitally put.

The book is composed of what may be called the narrative, accompanied by an interpretation or philosophy. If the reader accepts the philosophy, he will like the narrative, because the elements of causation are well chosen and meaningful. The facts and factors are all well laid hold of—especially the psychological. The purpose of the book is to show how social, political and economic forces grow out of mechanical invention. To put the matter tersely, social invention is the product of mechanical. One may wonder why the same agency has not produced like results elsewhere in the world, but perhaps that is a question for another writer to answer or for Mr. Burlingame to answer in another work.

One of the most delightful things about the book is that, for the casual reader—and most people read a book like this one more or less casually—it may be taken up almost anywhere and left almost anywhere. This is not to say that there is not the most careful concatenation, but rather that the individual links may be examined as units as well as serially or in their relationships. In other words, the book falls into self-significant parts; it also falls into an almost perfectly organized whole.

There is, moreover, both realism and romance about the history, if one may be permitted the use of these time-honored, if time-worn, words. It is the kind of presentation that sharpens a mind dulled by too much material of the text-book variety. It may be thought that the book dispels too many illusions to be good for everybody. It rather develops an interesting and probably wholesome skepticism of certain phases of modern industrialism as well as of much that has been accepted as historical fact regarding inventions and inventors.

Now as to the problems not met. We are informed of a collectivism or union (terms not too carefully defined, incidentally) brought about by the development of all the products of invention, but we are given only a faint suggestion of an almost equally imminent disintegration. If the author is to present a complete analysis of forces with potentialities for integration, why not a more careful analysis of the possibilities of disintegration? Why does this discussion end where it does? Is this unity—this collectivism—a lasting thing? The author gives hints here and there that he thinks not, but he nowhere follows up these hints to their logical conclusions. Perhaps the reason is to be found in his desire not to turn his thesis into a preachment, but he has spoken in homiletic vein sufficiently often to make the reader wonder why he has not followed up this side of the analysis. Is the unity of which he speaks inevitable? Will it endure? Of course, the author is under no compulsion to speculate on this particular matter, but the careful reader will wonder why he has not done so.

It has already been said that the book on the whole falls into a well-organized system of events and forces. Again, the critical reader will wonder why a significant chapter in the book should be

[1] "March of the Iron Men." By Roger Burlingame. Charles Scribner's Sons, xvi + 500 pp., illustrated. $3.75.

labelled "Capital" when indeed the whole book has primarily to do with the formation of capital and its effect upon society. Some of the items in this particular chapter are not vitally significant, and, lacking significance, are quite sure to cause wonder as to why they are thrown in under so significant a caption.

It should be said in conclusion, however, that these criticisms should not dissuade those looking for timely and important information from reading the book. It bears unmistakably the character of the author; it would not be so good a book if it did not. It may be that he is not altogether right, but those who think him wrong will at least be challenged, because where he has thrown himself most forcibly into the book he has presented important evidence. Even if his opinions are disliked, they can not for that reason be disregarded by thoughtful students. This is the first history of invention that is more than a rather thin recounting of facts; it is more than an enumeration—it is a synthesis of mechanical forces with the economic, political and social. It is not just another book; it is a challenging addition to the historical literature of the country.

J. E. Thornton
Brookings Institution,
Washington, D. C.

## THE SCIENTIST IN ACTION[2]

The title of this book suggests a volume intended for popular consumption. However, in spite of the interest of the matters dealt with and the general nature of the discussion, the degree of sophistication demanded by any reader who is to appreciate properly the significance of what is said is such that only real students of science are likely to gain more than a superficial insight into the subject-matter.

The foregoing remarks are not intended to imply any criticism of the work itself, which is admirable in scope and in treatment.

It is impracticable to attempt an adequate review of details. The first four chapters, entitled "The Scientific Outlook," commence by discussing what are called "the four qualities of scientific research." The first, which the author calls *action*, refers to the action of the individual leading to two typical products, the *facts*, which are representative of the second of the four qualities, and the *arrangement of the facts* in the form of theories, etc., which is representative of the third. Finally, we have the quality of newness in which the author distinguishes between the kind of research which blazes a new trail and that which is a mere modification or extension of some already familiar set of principles.

The third chapter discusses description versus the absolute truth, the significance of chance in natural laws; and it criticizes the attitude of mind which feels that certain things should happen because of a belief in the preconceived fundamentality of principles which have been born in the realm of other phenomena. Then the author has something to say in criticism of the assessment of values in various connections in scientific research, the main point being the ambiguity attending such assessment which exists in the absence of a more complete specification of the final aims to be attained.

In subsequent chapters, the question of observation is discussed in its various phases. Scientific observation of events is contrasted with the more frequent observation of all sorts of events by the layman in which there is often great diversity of opinion as to the facts themselves. The tendency of the mind to vision facts in their relationship to one another is emphasized, and discussion is made of the elements which determine the selection of what features of structure shall dominate the pattern. All such considerations are fundamental to

[2] "The Scientist in Action." By William H. George. Emerson Books. $3.00.

an analysis of what is meant by the construction of a theory in the modern sense of the word, and a discussion of present and past theories is made in the light of these considerations.

The last sections of the book are devoted to very practical elements, such as are embodied in questions like: "Is research getting more difficult?" or "Is specialization good or bad?" There are sections on "The provision for the needs of research in the form of research centers," "The cost of research," "The idealistic and routine research," "Facilities and freedom for free-lance research," "Research for humanitarian considerations," etc. Finally, there is a summary which helpfully collects together some of the salient features expressed in the main body of the text.

The whole book is characterized by a broadness of view-point which weighs the merits of the type of thinking done in physics in relation not only to thought in other sciences but also to thought in the everyday things of life. The book can be well recommended to those who desire to meditate upon the significance of their mental processes, and are not frightened by being called philosophers.

W. F. G. Swann,
*Director*
Bartol Research Foundation

## HOW MEN PERISHED IN THE ARCTIC[3]

In comparison with the struggles of explorers in the Arctic and the Antarctic regions against cold and physical hardships and lack of food and sometimes darkness, the famed expeditions of Xenophon and Marco Polo were excursions of a summer's day. Although the Antarctic is more forbidding physically than the Arctic, it was seriously attacked only after explorers had learned how to protect themselves under polar conditions. There were, of course, the tragic journey of Scott from the South Pole and the harrowing adventures of Shackelton, but on the whole the tragedies of polar explorations have occurred in the Arctic.

Soon after the discovery of North America explorers began to seek for a Northwest Passage to the Orient. Since Sir Henry Hudson was abandoned with his son in an open boat in high latitude, almost every generation has had its Arctic heroes and the exciting story of their struggles. In many cases the precise fate of those who have perished has remained a mystery. Now with the accumulation of discoveries of their remains and greatly increased knowledge of the hazards of the Arctic it is possible to complete with a high degree of probability many of these tragic stories. This is what Stefansson has done, and no one is better qualified for such a task because he has spent many years in the Arctic, often for months without sources of food or shelter except such as the country affords, and he not only survived but maintained full health and vigor.

Stefansson writes of the Arctic not only against a background of an enormous amount of experience in it, but he has engaged in a great amount of historical research concerning the five mysteries he has undertaken to solve. They are the disappearance in about 1520 of the Greenland Colony which had existed continuously from about 900 and at one time had about 9,000 inhabitants; the final story of the Sir John Franklin disaster, in point of numbers the greatest Arctic tragedy; the strange fate of Thomas Simpson, a bold seeker for the Northwest Passage; an explanation of the death of Andrée and his companions, who set out in a free balloon, in the summer of 1897, to drift over the Arctic and whose remains were not found until 1930; and, last, the fate of the Soviet

[3] "Unsolved Mysteries of the Arctic." By Vilhjalmur Stefansson. The Macmillan Company. xi + 381 pages and 4 maps. 1939. $3.50.

fliers who disappeared on an attempted flight, in 1937, from Russia to Alaska. This book is recommended for those who enjoy stories of harrowing adventures whose mysteries may be cleared up by historical research and processes of reasoning worthy of Sherlock Holmes.

F. R. M.

## PLANT GROWTH-SUBSTANCES[1]

SINCE the discovery, a few years ago, that roots can be induced to grow at will on any part of a plant simply through the application of certain chemicals, there has been, besides a good deal of regular commercial application, almost a craze of experimentation on the part of enthusiastic amateurs.

Several leading chemical companies have put the necessary compounds on the market, but a continuing handicap has been lack of suitable instructions in their use. This is now supplied in a compact book, entitled "Plant Growth-Substances." The first two chapters only are definitely dedicated to the layman. Chapter 1 tells in simple language what the substances are and the principles on which they operate. Chapter 2 tells how to use the commercial growth-substances in quickening the rooting of cuttings.

From there on, the book "goes technical" in the estimation of the author, although any one with a moderately good understanding of the freshman course in chemistry can make pretty smooth sailing of it. In any case, many persons will undoubtedly consider the book worth buying for the first two short chapters alone.

Two growth-stimulating chemicals are recommended by the author. The first, phenyl-acetic acid, is by far the cheaper, but the second, indole-acetic acid, is decidedly the more potent and hence can be used in the most dilute solutions. Proportions ranging from 1 to 100 parts of the acid to 100,000 parts of water are recommended.

Treatment of cuttings to induce roots is simple. Immerse the bottom third of the cuttings in the solution, and remove successive thirds after 12, 24 and 36 to 72 hours, respectively. This will establish the most favorable timing for the particular species under experimentation.

FRANK THONE

SCIENCE SERVICE

[1] "Plant Growth-Substances." By Hugh Nicol. xii + 108 pp. The Chemical Publishing Company. $2.00.

BYRD PARK IN RICHMOND

# THE PROGRESS OF SCIENCE

## RICHMOND ENTERTAINED THE ASSOCIATION

NEVER in any of its 102 previous meetings was the American Association for the Advancement of Science more adequately provided for and royally entertained than at its meeting in Richmond, Virginia, from December 27 to 31. To the traditional hospitality of the South was added the efficiency of the North. The lighter aspects of life were delightfully interspersed with the austerities of science. An almost continuously sunny sky smiled from above and a soft south wind gave early promise of spring.

It was not a small task to provide for the fifteen sections of the association and the 40 of its affiliated societies which met with it in Richmond. About 200 different sessions were held, before which about 1,700 addresses and papers were presented. All except one of the scientific sessions were held in four days, an average of about 50 sessions per day. It was necessary, therefore, to have over 50 rooms ranging in seating capacity from 50 to 1,200, and the auditorium in the Mosque, in which the general addresses were delivered, had a seating capacity of 2,500. The requirements for presenting scientific papers were so exacting that nearly all these rooms had to be equipped with projection apparatus and provided with means for being darkened. Indeed, it was necessary to show motion pictures in several of them, while nearly 100 microscopes were required for the demonstration programs of the biologists.

Even the housing of the 5,000 scientists who assembled in Richmond from all over the country presented a problem, for the requirements exceeded the capacity of the hotels. But the hospitable homes of Richmond were opened to its scientific guests, and not a complaint of unsatisfactory accommodations was heard. Before the meeting there were fears that the number of guest rooms for the scientists would be inadequate, but these fears were wholly unfounded, as our fears generally are.

It is impossible to give any comprehensive idea of the contents of 1,700 papers covering nearly the whole field of science. In fact, it would be impossible within reasonable limits even to outline the 240 papers on the program of the American Society of Zoologists or the 148 papers on the program of the Botanical Society of America. It should not be assumed that these two societies were the only ones in the biological fields, for there were nine others, several of which had very large programs. The biologists were by far the largest groups at the meeting which provided unsurpassed opportunities for investigators of living organisms to mingle and interchange ideas. At the same time the meeting often threw them into contact with workers in quite different fields—with chemists now synthesizing with amazing skill the complicated compounds produced by living organisms, with geologists accustomed to looking back along the paleontological record to the time when only simple forms of life existed, with anthropologists slowly lifting the curtain from the origin of man and the evolution of his culture, with psychologists exploring the intricacies of the human mind, with men and women whose interests range through essentially all the inanimate and animate universe about us and to the life and the minds within us. When in any earlier period of the world's history was there such a gathering? Certainly not during the barbaric splendor of ancient Egypt or Babylon, nor even when Aristotle and Plato taught in Greece. Never until the present day was there such variety of interests with such unity of purpose, or such general cooperation and unselfishness. Science has transformed the world

physically and mentally and is setting a model for its social and moral attitudes.

It was not Richmond alone that entertained the association and its affiliated societies. It was all Virginia and the entire Southeast. In physics there is a law that action and reaction are equal. Essentially the same law holds in matters of the mind and spirit. The Southeast put forth great efforts to make the meeting of the association at Richmond a splendid success. And reciprocally, the meeting must have been an inspiration to the Southeast. Its citizens demonstrated to themselves as well as to the remainder of the country what they can do. Every one of its scientists has a new pride in his section of our country. Every one of its universities and colleges will more ardently seek the truth. Every one of its papers will more generously report and support science. Every one of its broadcasting stations will increase the diffusion of science by radio. Every citizen will have a better appreciation of the importance of science and a higher regard for its spirit. Every boy and girl of the Southeast will have a better life because of the meeting of the association in Richmond.

Almost boastingly I make these apparently extravagant but literally true statements, for they express the spirit of science and the purpose of the association.

SIR RICHARD GREGORY AND DR. GEORGE D. BIRKHOFF

SIR RICHARD DELIVERED AN EVENING LECTURE ENTITLED "RELIGION IN SCIENCE," THE SUBSTANCE OF WHICH IS PRINTED AS THE LEADING ARTICLE IN THIS ISSUE OF THE SCIENTIFIC MONTHLY. DR. BIRKHOFF, RETIRING PRESIDENT OF THE ASSOCIATION, DELIVERED HIS ADDRESS ON "INTUITION, REVELATION AND FAITH IN SCIENCE" THE PRECEDING EVENING.

MR. LLOYD C. BIRD, CHAIRMAN OF THE GENERAL PLANNING COMMITTEE, WITH DRS. MITCHELL AND BIRKHOFF, PRESIDENT AND RETIRING PRESIDENT

The association was organized ninety years ago to advance the interests of science. More truly stated, it was organized to promote civilization, not in the material sense alone or even in the intellectual, but also in those rare qualities of superior human beings that are vaguely called things of the spirit. It is for this reason that the association holds its meetings in various cities throughout the United States and Canada, often at great inconvenience to many of its members. But temporary inconveniences are trivial in comparison with the advantages of having the general population familiar with the achievements of science and inspired by its ideals.

With such purposes the membership of the association is not limited to professional scientists. Its aims are not essentially different from those of all good men and women. Therefore it welcomes the cooperation of all persons, whether they are scientists or not, who have confidence in a better future for humanity and are desirous of aiding in its realization.

F. R. MOULTON,
*Permanent Secretary*

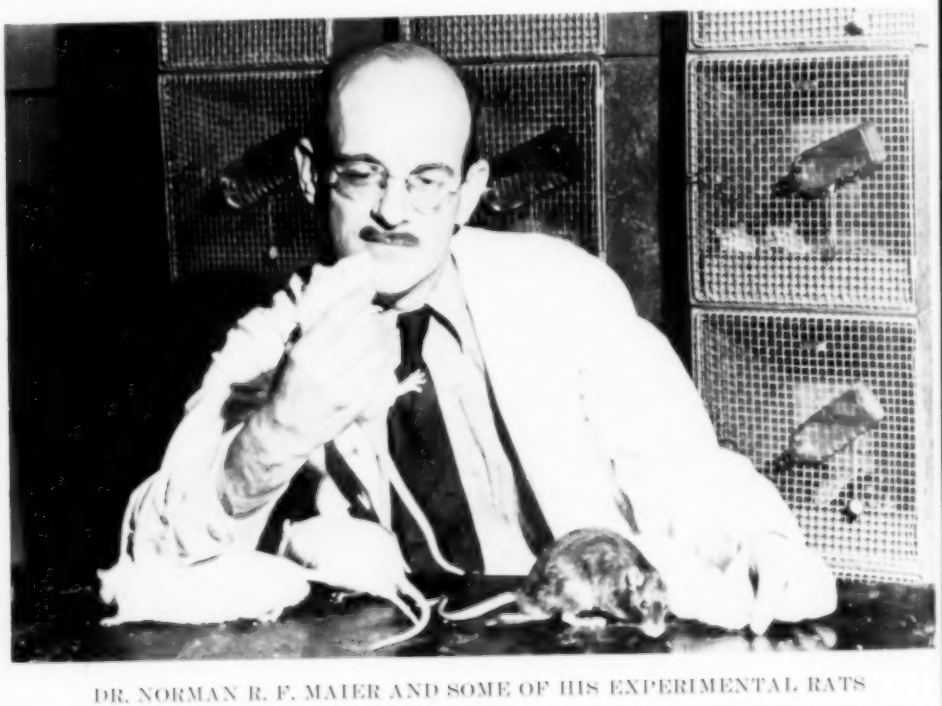
## THE THOUSAND DOLLAR PRIZE AWARD

EACH year for sixteen years the American Association for the Advancement of Science, through the generosity of an anonymous friend, has been able to award a thousand dollar prize for an outstanding contribution to science presented at its annual (December) meeting. This year the prize was awarded to Dr. Norman R. F. Maier, assistant professor of psychology in the University of Mich-

igan. The subject of his paper, which was illustrated by motion pictures, was "Experimentally Produced Neurotic Behavior in the Rat."

Animals have long been extensively used for experimentation on problems of nutrition, the effects of vitamin deficiencies, reactions to drugs and injections of microorganisms, the removal or transplantation of organs and on many other problems in biology and medicine. The progress of human physiology and of medicine owes very much to these experiments. Indeed, it is probable that a hundred human lives have been saved for every animal life they have cost. It is only recently, however, that the lower animals have been used extensively for experiments in psychology, the delays being due to overemphasis of what is vaguely called "instinct" and to the egotistical assumption that man is the only animal having reason. It has of course been suspected or known for a considerable period that such higher forms as the primates have the ability to reason, but Dr. Maier's conclusion reached in his doctor's dissertation in 1928, that rats possess this faculty was regarded by psychologists with much skepticism, an attitude that has been steadily weakened by subsequent researches.

It is clear that investigations of animal psychology are likely to throw much light on human psychology, at least to the ex-



DR. NORMAN R. F. MAIER AND SOME OF HIS EXPERIMENTAL RATS

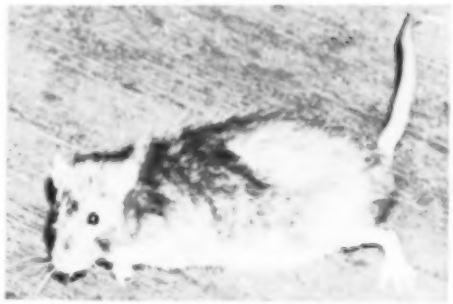
tent that animals and men have faculties in common, for animals have relatively simple mental processes, their ancestries and life histories may be determined, in such forms as rats they pass from infancy to maturity in short intervals and they may be controlled to any necessary extent during experiments or destroyed if advisable. The advantages may be greatest in using animals for experiments in abnormal psychology, and this is the field that Dr. Maier has been exploring.

Certain mental disorders are the most baffling of human diseases and among the

most serious. These neuroses are not produced by diseases, such as syphilis, or by injuries to the brain or by tumors, or by the use of narcotics. They appear without known physical cause. Yet they must have causes, whether they be in inheritances or something in life histories or in environmental factors. If animals are susceptible to similar abnormalities, they open up vast possibilities for controlled experimentation and an eventual understanding of certain types of insanity. Then remedies or preventatives may be hoped for. For these reasons the field which Dr. Maier has entered may become in time one of the highest importance.

In 1926 Pavlov produced neurotic behavior in dogs, and he has been followed by several other experimenters using generally similar methods. Dr. Maier introduced some new elements in the experiments. He first trained the rats to make a choice of two possibilities, not on the basis of obvious advantages of one over the other but by differences in the patterns on two cardboards to be jumped against. After the preference had been well established and associated with a definite pattern, he interchanged the patterns irregularly. In effect, he took the rats suddenly from an orderly universe into one that was chaotic and in which a choice could not be safely made. Then he introduced means of forcing them to make a choice in a chaos. In contrast with earlier experiments in the field, the restraints and pressures were psychological rather than physical. The consequences were more severe and convulsive in nature, similar to those in human hysteria. It may well be that the animal psychologist and the psychiatrist will work together to the great advantage of society.

The donor of the prize expressed the hope that it might be awarded generally to one of the younger scientists. Dr. Maier is thirty-eight years of age, having been born in the small town of Sebewaing, Michigan, on November 27, 1900.



A NEUROTIC RAT

IN CONVULSIONS AFTER HAVING GONE THROUGH VIOLENT PHASE OF TEARING ABOUT THE ROOM. EVIDENCE OF THE VIOLENT BEHAVIOR CAN, OF COURSE, ONLY BE SHOWN BY MOTION PICTURES.

He took his A.B. degree in the University of Michigan in 1923, majoring in the physical sciences. After teaching in a high school for a year, he returned to

THE JUMPING APPARATUS

A RAT JUMPS THROUGH CARD AND RECEIVES FOOD. A BLAST OF AIR IS USED TO OVERCOME RESISTANCE WHEN CONFLICTS ARISE. THE RAT SHOWN IS NORMAL AND MERELY DEMONSTRATES THE METHOD OF JUMPING.

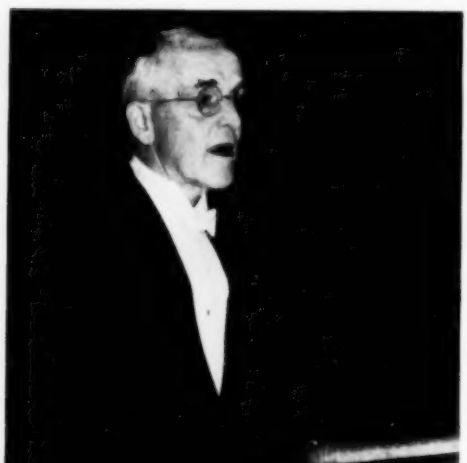
the university and took the A.M. degree in 1925, majoring in philosophy and psychology. He then spent a year in the University of Berlin, which at that time, as the center of the Gestalt Movement, was attracting the attention of psychologists in all parts of the world. He returned to Ann Arbor and took his doctor's degree in 1928. He then received a National Research Council Fellowship during 1929 and 1930 for study with Professor K. S. Lashley at the University of Chicago, after which he became a member of the Department of Psychology of the University of Michigan.

F. R. M.

## THE SYMPOSIUM ON MENTAL HEALTH

THE Symposium on Mental Health was an outstanding feature of the annual meeting of the American Association for the Advancement of Science at Richmond, Virginia. Conceived nearly three years ago by the officers of the Section on Medical Sciences as a most desirable project, over fifteen months were spent in planning the details and selecting the speakers. The American Psychiatric Association, the U. S. Public Health Service, the Mental Hospital Survey Committee and the National Committee for Mental Hygiene collaborated in developing the symposium.

The enigmas of mental illness are well recognized by eminent workers to be among the most challenging of all medical problems. Affecting as they do all social strata, they are a pervasive and debilitating influence in our national life, causing much suffering and misery and entailing enormous losses in terms of institutional maintenance, drains on public and private funds, reduced earning power, family disorganization and other financial and human costs. Mental disorders have been and are receiving increasing attention, but many of their aspects are confusing. As an example, one authority states that our bill for mental health amounted in 1937 to merely a billion dollars, which includes both loss of earnings and the cost of institutional and home care. In contrast, an equally qualified worker places the cost at three billion dollars by adding the price paid for unemployability. As to numbers actually afflicted, the former cites a figure of 266,618 institutional cases, whereas the latter by including the emotionally handicapped arrives at a figure of 14,500,000 persons, or more than 10 per cent. of the population of the United States. This lack of statistical and even medical unanimity should be attributed, partly at least, to the fact that our definitions of mental incapacity are legal rather than scientific. In any event, the most hopeful picture of the nation's mental disability is distressing enough. While rapid advances have been made in psychiatry and mental hygiene during the past few years, unfortunately these subjects have been set apart as specialities rather than incorporated in the general practice of medicine, due in no small



PRESIDENT WESLEY C. MITCHELL
AS HE OPENED THE SESSION ON TUESDAY EVENING.

part to the confusing terminology of psychiatry and the impression that it is more difficult than the other branches of the healing art.

The symposium was organized to provide an opportunity for specialists to gather under one roof for discussion and work on a common problem with free interchange of ideas. The development of the program was in many respects unique. Some fifty contributions were prepared and published in advance in a series of six brochures, one for each of the six sessions which were held during three days. These prepublication pamphlets served as a basis for discussion and were not read at the meetings. The first session was devoted to a critical survey of concrete scientific problems in the domains of psychiatry, psychopathology and contributory fields. It was pointed out that, despite the far-reaching advances in the treatment of the mentally ill in the past few years, more patients enter mental hospitals in greater numbers than leave. We are therefore faced with the prospect of a progressive increase in hospitalized mental diseases, necessitating the constant enlargement of institutional facilities, unless more effective means of prevention and treatment of mental diseases can be developed. The chief deterrents to the more vigorous prosecution of research in public mental hospitals at the present time are inadequate staffs, remuneration insufficient to attract the best workers, inferior clinical standards, difficulty in securing appropriate facilities and lack of funds for investigative work.

In the second session attention was focussed on the sources of mental disorder and disease. It was apparent from the evidence submitted that there are sources of mental diseases and disorder in the American community which, by the application of modern techniques, scientific knowledge and social effort, may be ameliorated and uprooted. Certain of these sources are due to innate factors, others are of external origin, involving infections such as syphilis, drugs, food deficiencies and social and cultural mishaps; and they are, to a great extent, modifiable from the standpoint of prevention, treatment and control.

The second day saw the statisticians, economists and social scientists appraising the magnitude and scope of the mental health problem, its financial and human costs, the manifold social problems associated with mental disease and its broad community and social aspects in terms of environmental influences and conditions, their modification and control. The discussion brought out the fact that a primary cause of our relative failure to cope with the situation has been the all too limited and restricted provisions we have made for the care and treatment of those mentally ill. Large sums have been spent for institutional care of the end result of mental disease, on bricks and mortar and other elementary requirements of an urgent physical nature, but not enough on the right type of clinical and treatment facilities and measures to meet the varied medical needs of this class of the sick and in proportion to their numbers. The underlying difficulty has been the failure, in most of the states, to adopt far-visioned comprehensive plans and programs with long-range objectives looking beyond the pressing needs of the moment to the more fundamental requirements of well-conceived and effectively administered therapeutic and preventive measures to deal with the problems of mental illness at their most vital points and at their source. This material led logically to a presentation of the influence of the physical and cultural environment on the direction of human affairs. The solution of this problem requires the collaborative study of psychiatrists, interested in interpersonal relations, and of anthropologists, interested in culture.

The practical aspects of the management and control of mental diseases and disorders were considered on the third

day. It has long been recognized that the care and treatment of the mentally ill and mentally defective in this country is an appropriate function of the state. It is increasingly obvious, however, that in many of the states this function has not been or can not be, under existing conditions, adequately discharged. Unfortunately, sound central state administration is not defended against the evils of adverse political control, interference and exploitation. The obvious remedy is the establishment of carefully constituted, non-partisan boards of control, the enactment of civil service laws and regulations and other protective devices, to the end that professional competence and merit only and not political considerations may govern in determining qualifications for appointment in this work. Particular attention was given to the pressing need for trained workers in the mental-hygiene field and the problem of developing a technical personnel adequate to the need.

The symposium served as a vehicle for the very practical purpose of promoting public interest and support looking to fruitful, nation-wide social action toward the amelioration, prevention and control of mental illness. It gave an authoritative and comprehensive set of principles to guide state and local governments and administrators in developing sound progressive and more nearly uniform policies and measures for the care and treatment of the mentally ill and defective. Inasmuch as mental illness is a national problem, the issues call for a union of scientific and social effort in a concerted, coordinated and more effective attack on mental disorders and disease than heretofore. Hence the need for an alliance of the medical, scientific, educational and social forces of the country that can contribute, in one way or another, to the solution of this problem became emphatically evident.

MALCOLM H. SOULE,
*Secretary for the Medical Sciences*

## CONSERVATION TEACHING—A PANEL DISCUSSION

RADIO effectively teaches science in the grades. It combines an element of novelty with reliable instruction; it is a help to the teacher who is inadequately trained in science, and it can impart scientific methods of investigating and thinking more effectively than text-books can.

This is the gist of a paper presented before the American Nature Study Society on December 29, 1938, by Dr. F. R. Moulton, permanent secretary of the American Association for the Advancement of Science. Miss Mary E. Leeper, of the Association for Childhood Education, stressed the values of science education for children of all ages. Science stimulates healthful play, artistic activity, keen observation and clear thinking —by kindergarten students as well as scientists. It also provides a medium for creative recreation in which whole families may participate, and such participation is vital to our social well-being. Science education therefore must be undertaken and planned for its social as well as its cultural values.

The American Nature Study Society will sponsor local clubs which will use radio programs and printed materials of the American Association for the Advancement of Science. Its past president, Dr. Edith M. Patch, already has taken part in one of the association's school broadcasts and has helped plan broadcasts for 1939. In addition to being a well-known entomologist, Dr. Patch also is senior author of one of the leading series of science readers and of several nature books for children.

Compulsory courses in conservation are likely to do more harm than good.

This was the opinion of several speakers in the panel discussion on conservation held by the American Nature Study

Society during its meeting in Richmond on December 28, 1938. These speakers cited their own experiences with schools in which state laws force the teaching of conservation for at least one year. In most cases, the courses which meet these laws are poorly planned, are squeezed into already crowded schedules, and are taught by unprepared teachers. Such courses make a bad impression upon students, and that bad impression is likely to continue into their adult lives.

Equally bad is the system by which visiting speakers from sportsmen's organizations lecture to grade school children on conservation. Most of these speakers are hunters, not conservationists; they are interested in destroying rather than saving; they lack thorough understanding of the many phases of conservation and the extent to which these phases interlock. The need for such understanding, with a conservation program which starts with the ground and extends to man, was stressed by Dr. Paul Sears, author of "Deserts on the March."

Conservation education which takes exhibits and demonstrations into the village and country schools was described by John C. Caldwell, of Tennessee. Mr. Caldwell has a car, a trailer and a tent; he can hold a meeting in a town or stop to work with children by the roadside. Tennessee's trailer educational service has visited 350 schools and held 600 meetings. Each visit is intended to begin a conservation project in which teachers and children cooperate. Once such a project is begun, there is no need for a law to force the teaching of conservation.

CARROLL LANE FENTON

DR. FRANK PIERREPONT GRAVES
WHO DELIVERED THE FOURTH ANNUAL LECTURE SPONSORED BY UNITED CHAPTERS OF PHI BETA KAPPA. THE SUBJECT OF HIS ADDRESS WAS "IS EDUCATION A SCIENCE?"

## BROADCASTS FROM THE ASSOCIATION MEETING

A TOTAL of 34 broadcasts, several over national networks, were delivered by scientists attending the meeting of the association at Richmond. The subjects ranged from theories of the origin of the earth to how we taste, from a discussion of conditions in Greenland to game hunting in Fiji. The after-dinner speeches of the press dinner were carried by a local station for two and one half hours.

The broadcast of Sir Richard Gregory on "Religion in Science" stimulated the largest number of listeners to write expressions of approval and for copies of the address. Perhaps this is an indication of a longing for some substantial

new basis for religious beliefs, or perhaps it is an evidence of the vague fears of impending disaster that now pervade the world. In any case, it carries the lesson that scientists should no longer think of science as something apart from the general currents of life but as an influence that pervades every phase of our existence.

It is a difficult task to arrange for 34 broadcasts in four days by men in a strange city who are not generally accustomed to the exactions in time of the radio. Not only must all broadcasts begin on appointed times within a very few seconds, but they must be almost exactly of prescribed lengths. There are problems of delivery before the microphone, which is no more inspiring than a one-way conversation over a telephone. Yet the arrangements for the broadcasts were most efficiently taken care of by Professor G. W. Jeffers, of State Teachers College, Virginia, and the broadcasts themselves were of a high order of excellence. The association and the public owe much to Professor Jeffers and to the broadcasting stations for making available by radio so many interesting scientific discussions.

From the point of view of specialists such broadcasts of science as those delivered at Richmond may not seem to be important. But it should be remembered that they reach the masses on whom the higher levels of society ultimately rest. Consequently, it may be that these influences, many times repeated, will eventually have most important effects. Is it not true that the civilizations that have failed all went down because of the degradation and disintegration of their masses?

F. R. M.

## THE PRESS AT THE VIRGINIA MEETING

The annual winter meeting of the American Association for the Advancement of Science at Richmond was probably the most thoroughly "covered" scientific gathering in history.

From the press room in the John Marshall Hotel well over a half million words were distributed by wire and by mail. Columns were printed daily by newspapers from coast to coast. Besides the four press associations represented—the Associated Press, the United Press, the International News Service and Science Service—twenty-one daily papers had special correspondents in Richmond to report this meeting.

The meeting was by all odds the "big news" of the week—notably free of crime, international complications or political scandals. Although no major story "broke" at Richmond, such as the first announcement of a scientific discovery of universal significance, yet the news value of the papers presented remained throughout on a high level. There was very little of the stale or trivial.

The exceptional coverage may be attributed to various reasons. First, the facilities offered the correspondents were such as have never been equaled at such a gathering. The work of Dr. Sidney S. Negus and his colleagues in charge of press arrangements for the Richmond committee may well serve as an example for such local committees to strive to equal for many years to come.

Secondly, it is hardly possible to express too warmly the appreciation of the press writers for the great abundance of material provided in advance of the meeting and for the efficiency with which the office of the permanent secretary made it available to the science writers.

Thirdly, probably more than ever before, the reporters were challenged to do their best by the extraordinary hospitality of Richmond and of the Virginia committee. The major event preceding the opening of the convention itself was

VIRGINIA STATE CAPITOL AT RICHMOND

SHOWING THE GOVERNOR'S MANSION IN THE DISTANCE AND THE EQUESTRIAN STATUE OF GEORGE WASHINGTON IN THE FOREGROUND.

a dinner for the press, arranged by Dr. Negus and his associates, attended by more than 200 Virginia editors, at which the members of the National Association of Science Writers were honored guests. Throughout the week luncheons, typewriters, messenger service and a special recreation lounge were provided for the newspapermen. Dinners were arranged for them at the homes of prominent Richmond families. The visiting press felt that it owed for all this more than it could hope to pay but that some compensation might be given by the fullest and most accurate reports possible. Every reporter was spurred to do his very best work. The press room was a busy place practically 24 hours a day.

The reporters hope they did a good job—and this is most particularly true of those of us who happen to be members of the National Association of Science Writers, for we feel that we have played some small part in an extraordinary development which reached its culmination, to date, at Richmond. This is the rapid development of friendship, mutual appreciation and mutual confidence between the scientist and the newspaper man, which has taken the place of suspicion on the one hand and irresponsibility on the other.

There were no broken confidences nor, we hope, seriously inaccurate or distorted reports. The attainment of this happy result has been the culmination of a labor of years. A noteworthy contributor to this achievement has been Austin H. Clark, for many years the press director of the American Association for the Advancement of Science, and the tokens of warm regard presented to him at the press dinner on Monday night were inadequate expressions of our gratitude.

Members of the National Association of Science Writers who covered the summer meetings of the association at Ottawa last June were warm in their praise of the hitherto unequaled press arrangements in charge of Ernest Rhodes, of the Dominion Department of Agriculture. Ottawa eclipsed anything that had gone before; Richmond surpassed Ottawa.

THOMAS R. HENRY,
*President, National Association of Science Writers*

## MOTION PICTURES AT THE RICHMOND MEETING

EACH year motion pictures play an increasingly important rôle in the meetings of the American Association for the Advancement of Science. This year some twenty of the papers presented in the special sessions used motion pictures as a method to demonstrate, in part or in entirety, the results of research. About one third of them were photomicrograph films in the field of the biological sciences.

An added feature of the Science Exhibition was the more or less continuous showing over a period of two and one half days of a wide variety of technical and popular scientific films. Many of the research films shown in the special sessions were repeated before this more general group. The United States Film Service made a substantial contribution by providing a series of government films. "Three Counties against Syphilis" was noteworthy. "The Plow that Broke the Plains" and "The River" were repeated two or three times, upon request, for the audience was a continuously changing one.

Color and sound films were liked best. The bird pictures contributed by Dr. Gross and Dr. Pirnie and the insect pictures of Dr. Melander and Mrs. Brues were at times breath-taking in their beauty.

In general the film exhibition was well attended; the hall, seating 175 people, averaged a little less than half full. The attendance during the first part of the morning was low; on the other hand, at a popular picture in the late afternoon every seat would be occupied, with people crowding around the door for a view of the screen.

In general, the addition of the motion pictures to the Science Exhibition proved popular. It might have been anticipated that visitors would be distracted by them and spend less time than they otherwise would have done in the exhibition hall proper, but the consensus of opinion seems to be that, as a whole, the showing of the motion pictures increased rather than decreased the attention received by the exhibits.

The latter opinion received some confirmation when a group of biological motion pictures by Chambers, Bailey and Strandskov were shown at four o'clock on Thursday afternoon. Notice of this special showing was posted in the morning at the Medical College, the meeting headquarters of the zoologists, and a number of biologists went down to the Mosque especially to see them.

The motion pictures of native and animal life in Sumatra shown by Dr. Wm. M. Mann, of the National Zoological Park, attracted by far the largest audience of any film. These pictures, shown through the courtesy of the National Geographic Society, were exhibited on Saturday morning in the auditorium of the Mosque in order to accommodate the great number who came to view them.

W. C.